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THE CLIMATE OF THE CENTRAL NORTH AMERICAN GRASSLAND*

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INTRODUCTION

THE steppes of the Great Plains and the Prairies of the mid-West have long been of interest to scholars in many fields because of the significance of those regions in the white settlement of Anglo-America. The physical aspects of the Grassland alone have provided the topics for an enormous number of studies.[1] In the natural sciences the explanation of the geographical distribution of the original grass vegetation has long been an enigma. This has been particularly true of the Prairies.

One important segment of the knowledge which will lead to an understanding of the distribution of original grassland is an understanding of the distinctive climatic characteristics of the region and of their significance to wild vegetation. The present paper is added to the vast literature already published primarily as a contribution to the regional climatology of the Grassland. The ecological literature is reviewed very briefly to show how the findings of the grassland ecologists fit the facts of the present climatic pattern of the region and to complete the background for a discussion of the prehistoric climate. It is hoped that the study will lead to a better understanding of the role of climate in determining the regional pattern of the original Grassland east of the Rockies in Anglo-America.

Scope of the Study

The following discussion is concerned with the general wedge of predominantly grass vegetation and park borderland east of the Rockies as it is outlined in Figure 1. The countless and complex irregularities in the actual boundaries between forest

* The author is especially indebted to Professor Reid A. Bryson of the Department of Meteorology, Professor John T. Curtis of the Department of Botany, and Professor Glenn T. Trewartha of the Department of Geography, all of the University of Wisconsin, for their counsel during the course of this study.

[1] The term "Grassland" is used in this paper to refer to the regions which had a vegetation cover predominantly of grass at the time of white settlement and which lie east of the Rocky Mountains.

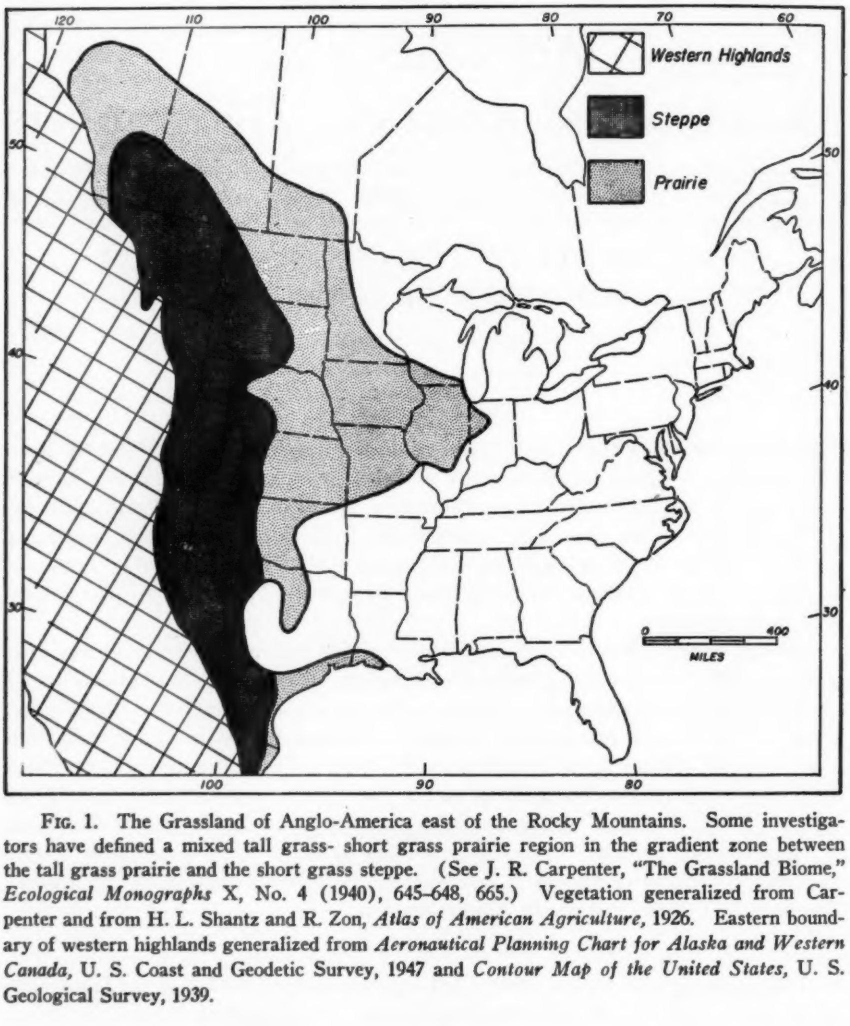

Fig. 1. The Grassland of Anglo-America east of the Rocky Mountains. Some investigators have defined a mixed tall grass- short grass prairie region in the gradient zone between the tall grass prairie and the short grass steppe. (See J. R. Carpenter, "The Grassland Biome," *Ecological Monographs* X, No. 4 (1940), 645-648, 665.) Vegetation generalized from Carpenter and from H. L. Shantz and R. Zon, *Atlas of American Agriculture*, 1926. Eastern boundary of western highlands generalized from *Aeronautical Planning Chart for Alaska and Western Canada*, U. S. Coast and Geodetic Survey, 1947 and *Contour Map of the United States*, U. S. Geological Survey, 1939.

and prairie and the local differences in original vegetation within the Grassland are recognized, but they are problems of a different scale and will not be dealt with in this study. The general boundary *zones* of the Grassland—the zone of transition from forest to prairie and the zone of transition from tall to short grass—followed the lines shown in Figure 1, and it is the trend of those boundary zones with which this study is concerned.

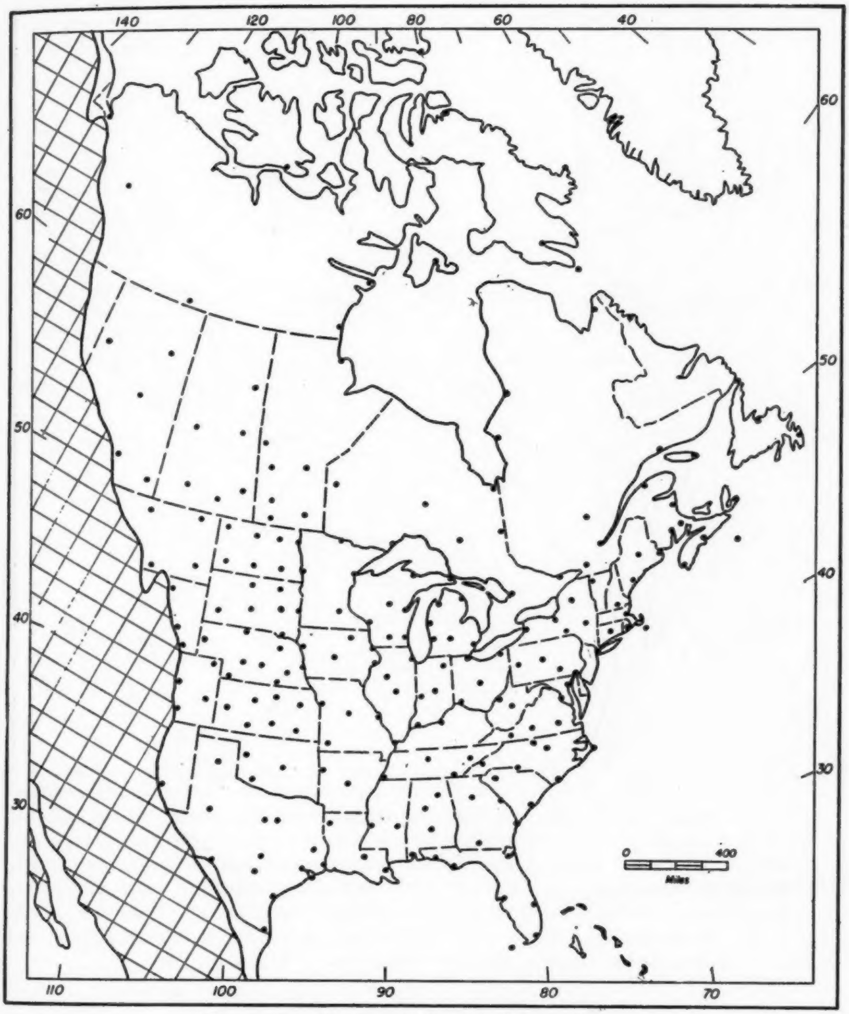

FIG. 2. Distribution of climatological stations.

Climatological Stations

Climatic statistics prepared for the maps in this study are based upon data from the observing stations shown in Figure 2. This group includes the first-order U. S. and Canadian stations whose records are published in the U. S. *Monthly Weather Review.* The first-order stations have been supplemented by nineteen other Weather Bureau stations on the Great Plains. This grid of observing stations

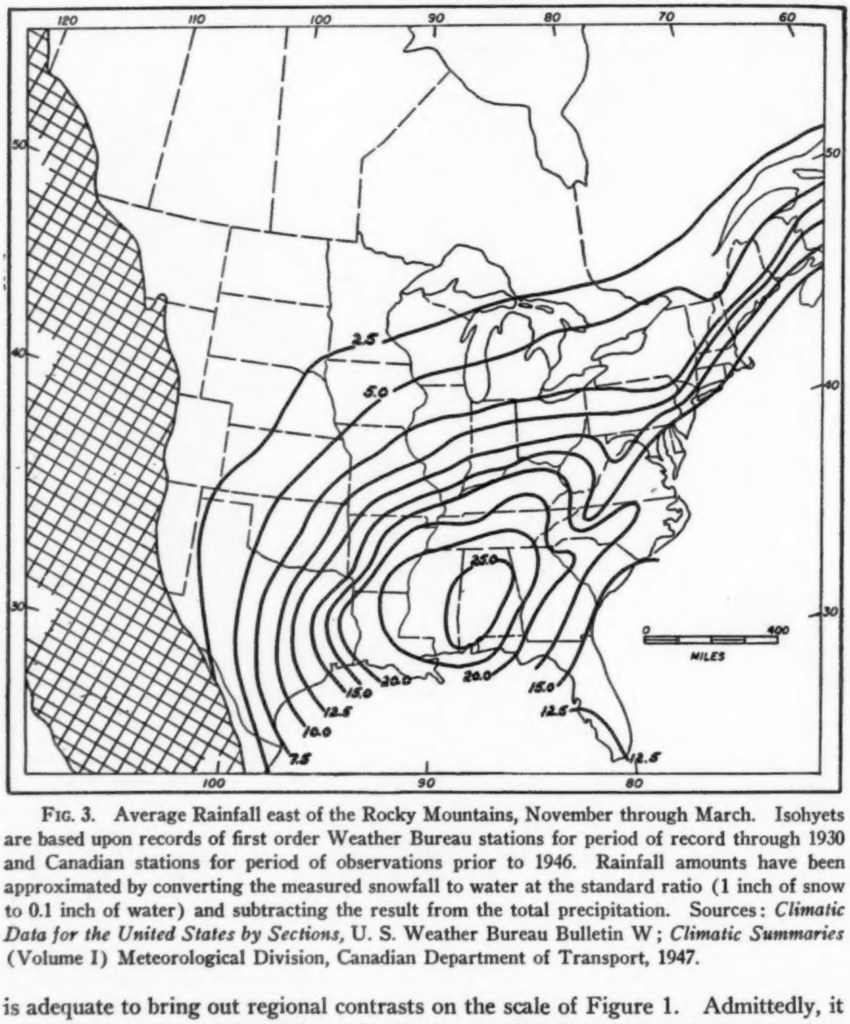

FIG. 3. Average Rainfall east of the Rocky Mountains, November through March. Isohyets are based upon records of first order Weather Bureau stations for period of record through 1930 and Canadian stations for period of observations prior to 1946. Rainfall amounts have been approximated by converting the measured snowfall to water at the standard ratio (1 inch of snow to 0.1 inch of water) and subtracting the result from the total precipitation. Sources: *Climatic Data for the United States by Sections,* U. S. Weather Bureau Bulletin W; *Climatic Summaries* (Volume I) Meteorological Division, Canadian Department of Transport, 1947.

is adequate to bring out regional contrasts on the scale of Figure 1. Admittedly, it would not be adequate for an investigation on a scale which dealt with the boundary of the Grassland in more detail. The stations used have the advantage of long and comparable records, except those in Arctic Canada.

THE UNIQUE CLIMATIC CHARACTERISTICS OF THE GRASSLAND

Mean Winter Precipitation

Most of Anglo-America's winter rain falls upon the southeastern United States, southeast of the Grassland. The mean monthly rainfall in winter declines rapidly

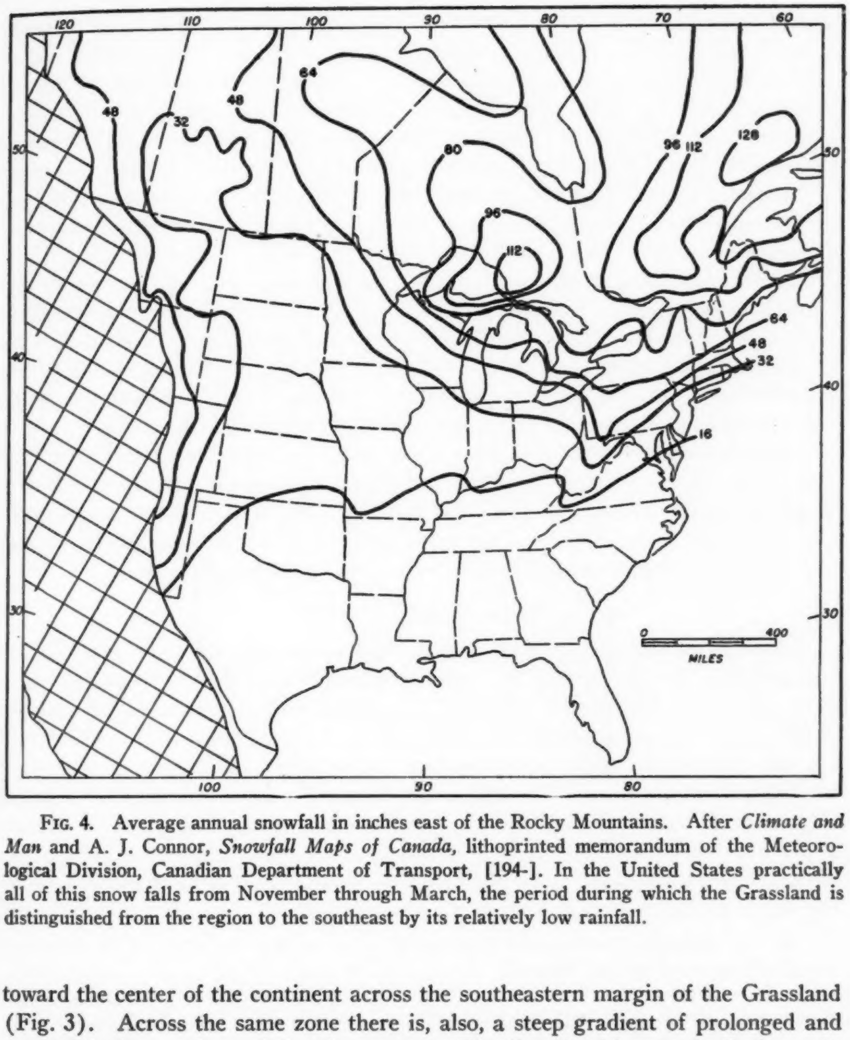

FIG. 4. Average annual snowfall in inches east of the Rocky Mountains. After *Climate and Man* and A. J. Connor, *Snowfall Maps of Canada,* lithoprinted memorandum of the Meteorological Division, Canadian Department of Transport, [194-]. In the United States practically all of this snow falls from November through March, the period during which the Grassland is distinguished from the region to the southeast by its relatively low rainfall.

toward the center of the continent across the southeastern margin of the Grassland (Fig. 3). Across the same zone there is, also, a steep gradient of prolonged and torrential winter rains and thunderstorms.[2] The Grassland has markedly less rain and fewer heavy rains during winter than the region of forests to the southeast.

Most of North America's snow east of the Rockies falls over the coniferous forests of Canada and the northeastern United States. The most rapid decline in

[2] See *Thunderstorm Rainfall,* U. S. Weather Bureau Hydrometeorological Section, Vicksburg, Miss., 1947, Part 2, Figs. 53, 55, 61, 63; also S. S. Visher, "Regionalization of the U. S. on a Precipitation Basis," *Annals of the Association of American Geographers,* XXXII, No. 4 (Dec., 1942), 355–370.

mean winter snowfall between eastern Canada and the dry continental interior occurs along the northern margin of the Grassland (Fig. 4). This marked difference in snowfall across the boundary zone between the Grassland and the forests to the north and northeast reflects three different factors. First, the mean total precipitation for the period December-February is greater in the northern forests than in the Grassland to the south and southwest. Second, a higher percentage of the winter precipitation falls as snow north of the Grassland because winter temperatures are more consistently below freezing. Finally, the length of the frost and snow season increases toward the north.

The average snow cover on the ground at the end of each winter month displays the same pattern as the mean winter snowfall.[3] The relatively rapid increase in snow cover to the northeast of the Grassland reflects two factors: the greater snowfall over the northeastern and northern forests, and the greater persistence of the snow blanket because of the lower frequency of southerly and southwesterly winds and winter thaws in the forest region than over the Grassland to the south.[4]

Thus the Grassland occupies a unique position in the winter precipitation patterns over North America east of the Rocky Mountains. In the north, where there is frequent severely cold weather, the Grassland lacks the persistent and deep blanket of snow which is characteristic of the northern forests. In the south, the Grassland lacks the heavy winter rainfall that is typical of the southeastern forests.[5]

Mean Summer Rainfall

Whereas the entire Grassland has unique, relatively homogeneous precipitation characteristics in winter, only the short grass region is climatically distinctive in most summers. The steep rainfall gradient which marks the southeastern margin of the prairies in winter shifts northwestward during the spring and coincides with the tall grass-short grass boundary zone in summer. The mean May-August rainfall amount is between 12 and 16 inches everywhere in the United States east of approximately the 100th meridian, except along the South Atlantic and Gulf coasts (Fig. 5). Mean summer rainfall decreases very sharply westward from the 100th meridian across the Great Plains. The westward decrease is greatest across the southern Plains in May and June and across the northern Plains in July and

[3] See A. J. Connor, *op. cit.*, and weekly snow cover maps in the U. S. Weather Bureau, *Weekly Weather and Crop Bulletin.*

[4] The frequent winter thaws on the Great Plains as far north as the Canadian border have been cited by T. A. Blair (*Climatology,* 1942, p. 186) and C. G. Bates ("Climatic Characteristics of the Plains Region," *Possibilities of Shelterbelt Planting in the Plains Region,* Washington, 1935, p. 86.).

[5] It is the characteristic dry winter of the region which caused a wedge of "moist subhumid" climate to appear in approximate coincidence with the Prairie peninsula in Thornthwaite's older climatic system. The wedge appears on the map of average P-E index for the entire year, but it does not appear on the map of average P-E index for the growing season, where the effect of winter precipitation patterns is removed. See C. W. Thornthwaite, *Atlas of Climatic Types in the United States, 1900–1939,* Washington, 1941, Plates, 3, 4, and James C. Malin, *The Grassland of North America,* 1947, p. 398.

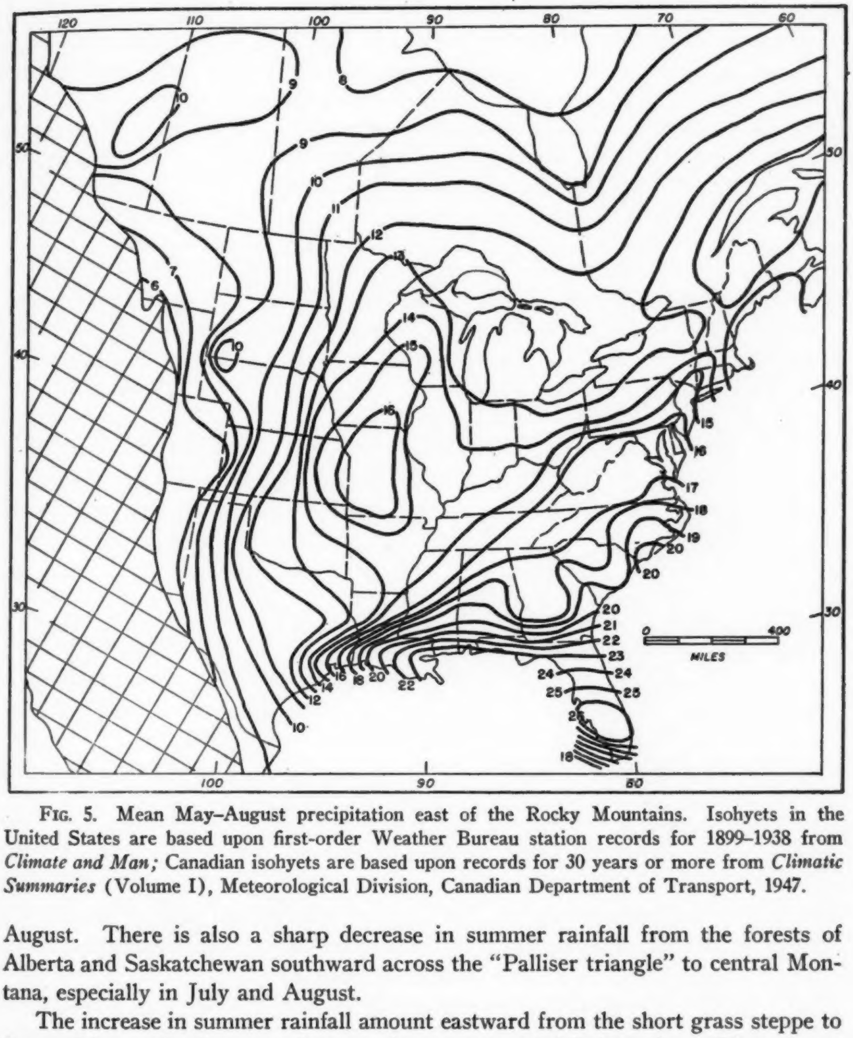

FIG. 5. Mean May–August precipitation east of the Rocky Mountains. Isohyets in the United States are based upon first-order Weather Bureau station records for 1899–1938 from *Climate and Man;* Canadian isohyets are based upon records for 30 years or more from *Climatic Summaries* (Volume I), Meteorological Division, Canadian Department of Transport, 1947.

August. There is also a sharp decrease in summer rainfall from the forests of Alberta and Saskatchewan southward across the "Palliser triangle" to central Montana, especially in July and August.

The increase in summer rainfall amount eastward from the short grass steppe to the prairie results from an increase in average rainfall intensity. There is no appreciable change in the total number of days with precipitation as one moves from the western to the eastern side of any of the northern and central Great Plains states (Fig. 6). But the probability of an inch or more of rain falling from one storm doubles.[6] The increase in summer rainfall northward from the steppe in

[6] See Andrew D. Robb, "Rains in Kansas," *Monthly Weather Review,* LXVI, No. 10 (Sept., 1938), 277–279; see also *Thunderstorm Rainfall,* Part 2, Fig. 58.

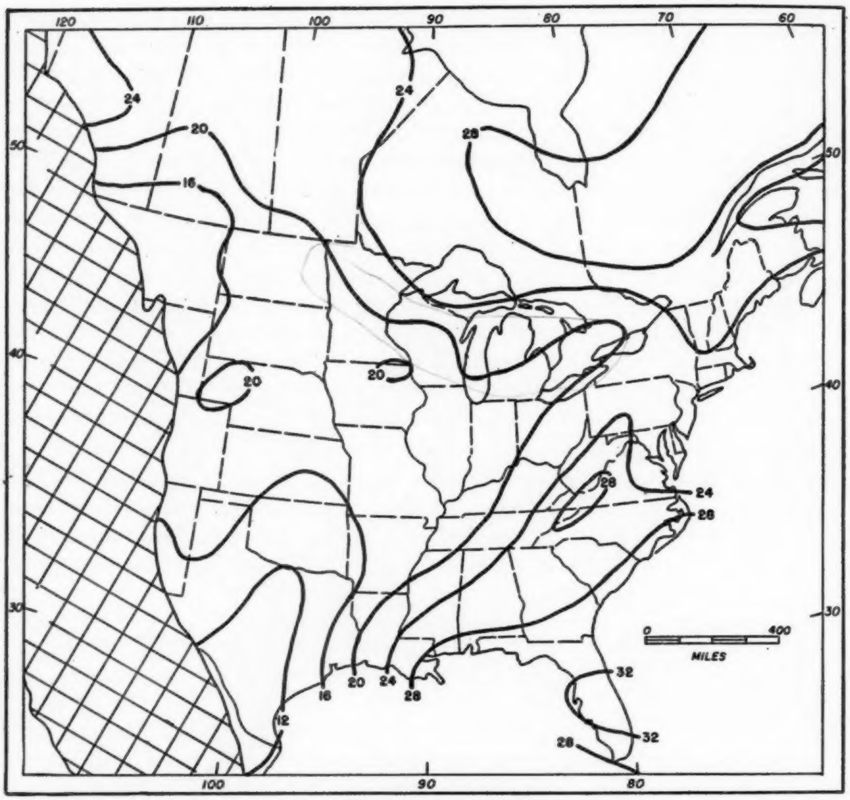

FIG. 6. Average number of days with 0.01 or more inches of rainfall east of the Rocky Mountains during July and August. Sources: *Thunderstorm Rainfall* and Canadian *Climatic Summaries.*

Montana across southern Alberta and Saskatchewan results from an increase in the number of days with rain (Fig. 6). Furthermore, it is accompanied by an increase in the reliability of summer rainfall (see below).

In addition to the summer rainfall gradients which outline the short grass region there is a small but abrupt increase in the number of days with rain at the northern edge of the prairie peninsula (Fig. 6). This means that summer rains have a higher average rate of fall in the prairie peninsula and that the length of time between the rains is greater than it is in the forest region to the northeast. It also means that the average cloud cover and relative humidity in summer are lower in the prairies.[7]

[7] The differences in cloud and relative humidity between the prairies and the forests to the northeast are shown by the maps of mean percent of possible sunshine published during July and August as a supplement to the U. S. Daily Weather Map (Published daily at Washington by the U. S. Weather Bureau) and *Climate and Man* (U. S. Dept. of Agriculture Yearbook), 1941, p. 734.

It is now possible to summarize the mean climatic gradients which characterize the boundaries of the Grassland. The northern margin of the region is characterized by (1) a relatively steep gradient of winter snowfall and snow cover and (2) a small but abrupt increase in frequency of days with rain in summer and an accompanying increase in cloud cover and relative humidity. The southeastern margin of the prairies is marked by a zone of steep winter rainfall gradient. This zone of steep rainfall gradient, from its base on the Texas Gulf coast, swings across the Prairies during the spring, and it marks the boundary between the prairie peninsula and the steppe in summer.

The climatic gradients summarized in the preceding paragraph are part of the average picture. The characteristic winter drought sometimes spreads over the entire Grassland in summer. It is illuminating to examine the climate of the Grassland during periods of great summer drought.

Summer Rainfall Variability and Regional Drought

Climatic Coherence of the Grassland.[8]

There has been a tendency for America's great rainfall deficiencies east of the Rockies to be concentrated in relatively few years and to be widespread during those years. Tannehill has recently pointed out this fact,[9] and one would probably draw the same conclusion from an examination of periodical literature and historical writings. Furthermore, the tendency has been for the drought to be concentrated in the Grassland. This appears if one examines the coincidence of dry years in the states east of the Rockies. The U. S. Weather Bureau defines 35 state climatological districts east of the Rocky Mountains (33 individual states plus New England and Maryland-Delaware, including four states which overlap the Rockies and Great Plains). The precipitation records of the ten driest years in each of these districts for the 53-year period, 1886–1938, have been tabulated and published.[10] There is a total of 350 "district dry years"—the ten driest years for each of the 35 districts. Presumably, these years might be distributed at random throughout the 53-year period. However, a tabulation by the author showed that fifteen of the 53 years accounted for nearly two-thirds (61%) of all of the 350 "district dry years." Furthermore, these particular years are fifteen of the seventeen driest in 53 years for the country as a whole. Thirteen of these fifteen great dry years fall nicely into one of two groups. In four of the years the maximum state rainfall deficiencies occurred in the southeastern states, centering in Tennessee, Alabama, and Mississippi.[11] In the other nine years the maximum state rainfall deficiences occurred in the mid-West and Great Plains, centering in Illinois, Iowa, Nebraska, and Kansas.[12] After the present author had made this tabulation, he found that the same

[8] The term "coherence" is used in this case to mean the degree of synchronization of climatic events. See V. Conrad, *Methods in Climatology,* 1944, pp. 148–150.

[9] I. R. Tannehill, *Drought,* Princeton, 1947, pp. 68–73.

[10] *Maps of Seasonal Precipitation,* U. S. Weather Bureau Publication 1353, 1942.

[11] 1887, 1904, 1914, and 1925.

[12] 1894, 1895, 1901, 1910, 1917, 1930, 1933, 1934, and 1936.

thing had been done, with data up to 1930, nearly two decades ago by A. J. Henry.[13] Although Henry was not especially concerned with the regional aspect of the problem, he noted in passing that, on the basis of dependability of their precipitation and a tendency for their dry years to occur simultaneously, three nuclear groups of states east of the Rocky Mountains appear to be distinctive. Henry listed first, New England, New York, New Jersey, Pennsylvania, and Michigan; second, Louisiana, Mississippi, Alabama, and Florida; and third, the Great Plains states plus Minnesota, Iowa and Missouri. Of course, the use of such large statistical units as states makes this sort of undertaking a rather crude geographical reconnaissance. Nevertheless, the grouping of mid-Western prairie states with the Great Plains states and their separation from the northeastern and southeastern states is an interesting result at which both Henry and the present author arrived. The grouping suggests that the climate of major drought years has set off the prairie peninsula from the rest of the mid-West. The same idea has been suggested by Visher and by Transeau.[14]

Foster, in 1944, computed and mapped the correlation between annual precipitation at Omaha and other stations in the mid-West and Great Plains.[15] He found that the positive correlation decreased relatively gradually to the northwest, west, southwest, and east from Omaha, but relatively rapidly toward the northeast and southeast (Fig. 7). His map strongly suggests the shape of the Grassland. It demonstrates that a dry year at Omaha is more likely to be a dry year also at, for example, Davenport, Dodge City, or Bismarck, than beyond the margins of the Grassland at Minneapolis or St. Louis. This "relative synchronization of climatic events"—as Foster termed it—is a type of climatic honogeneity not generally attributed to the Grassland and is generally neglected in regional climatology. The reason for this coherence of the Grassland climate will be discussed in the section of this paper dealing with the mean airflow across the Grassland.

Relative Variability of Summer Rainfall

The relative variability of June-August rainfall is high in the Grassland and decreases rather rapidly at the margins of the region (Figure 8). This fact is especially important because summer accounts for a larger part of the total annual precipitation in the Grassland than it does in the adjoining forested regions. The high summer rainfall variability of the Great Plains region has long been appreciated generally, but it is not often pointed out in connection with the climate of the prairie peninsula. Since the long-time average precipitation—either annual or warm sea-

[13] A. J. Henry, "The Calendar Year as a Time Unit in Drought Statistics," *Monthly Weather Review,* LIX, No. 4 (April, 1930), 150–154.

[14] S. S. Visher, "The Desirability of More Maps of Regional Contrasts in Non-Average Temperatures and Precipitation with Illustrations from Indiana," (Abstr.), *Annals of the Association of American Geographers,* XXVI, No. 1 (March, 1936) 85–86; E. N. Transeau, "The Prairie Peninsula," *Ecology,* XVI, No. 3 (July 1935) 423–437, esp. 436.

[15] Edgar E. Foster, "A Climatic Discontinuity in the Areal Correlation of Annual Precipitation," *Bulletin of the American Meteorological Society,* XXV, No. 7 (Sept., 1944) 299–306.

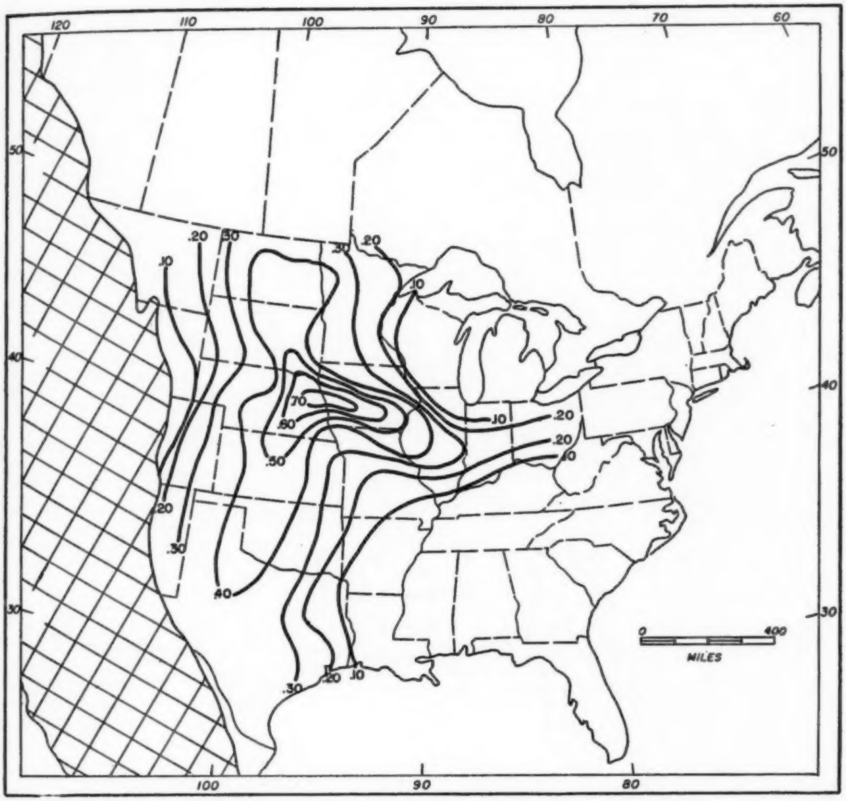

FIG. 7. Lines of equal correlation coefficient of annual precipitation, Omaha vs. other stations in the mid-West and Great Plains, approximately 1900–1939. (After Foster, with additional data in the mid-West and southern Great Plains.)

son—is no less in the prairie region than in the rest of the mid-West, the greater variability indicates that the prairies are subject to more frequent and severe drought than the areas of similar average rainfall amount to the east, northeast, and southeast. In other words, the low-rainfall climate of the Great Plains is more likely to spread eastward occasionally across the prairie region than to the north or south of the prairies. The eastward extent of occasional "steppe" years mapped by Russell for the period 1901–1920 is in accordance with this conclusion.[16]

[16] R. J. Russell, "Dry Climates of the United States, II, Frequency of Dry and Desert Years," *University of California Publications in Geography,* V (1932), 245–274. See map of dry years.

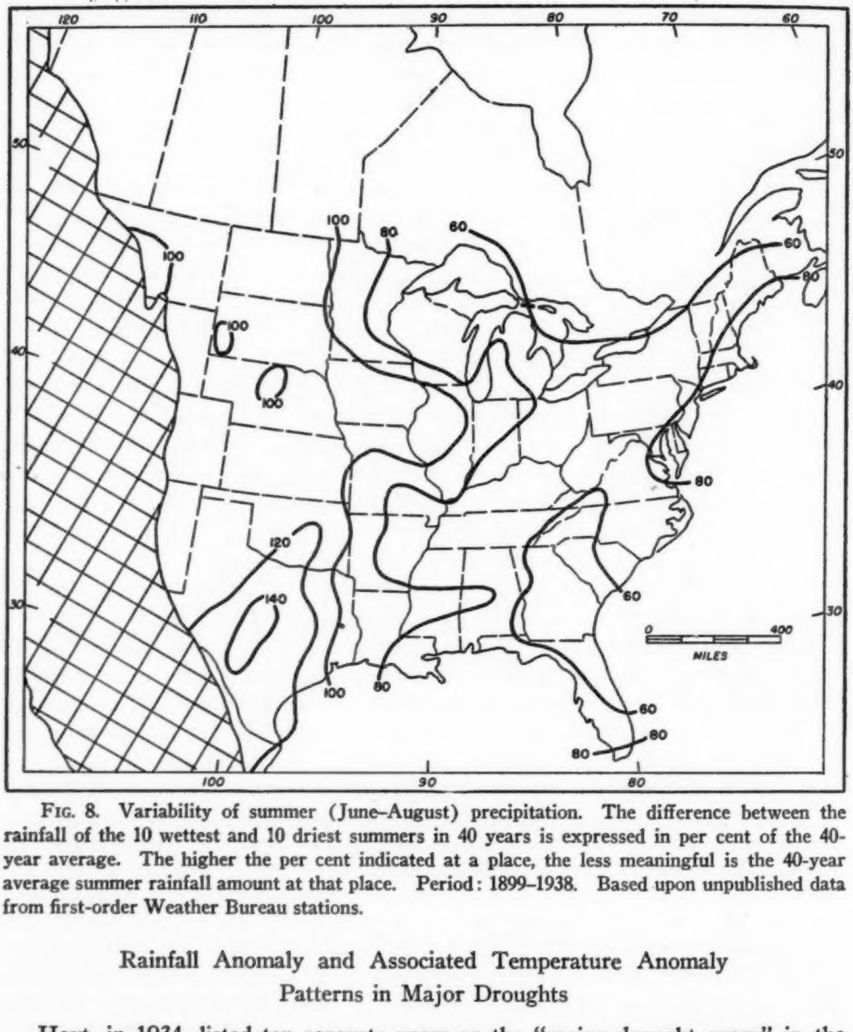

Fig. 8. Variability of summer (June–August) precipitation. The difference between the rainfall of the 10 wettest and 10 driest summers in 40 years is expressed in per cent of the 40-year average. The higher the per cent indicated at a place, the less meaningful is the 40-year average summer rainfall amount at that place. Period: 1899–1938. Based upon unpublished data from first-order Weather Bureau stations.

Rainfall Anomaly and Associated Temperature Anomaly Patterns in Major Droughts

Hoyt, in 1934, listed ten separate years as the "major drought years" in the period during which there has been a fairly complete network of weather observing stations over all of the United States and southern Canada.[17] Those years are 1889, 1890, 1894, 1901, 1910, 1917, 1930, 1931, 1933, and 1934. To this earlier list should be added 1936, the last severe drought year of the 1930's. The years selected represent the great droughts of the late 1880's and early 1890's and of the 1930's. Ex-

[17] John C. Hoyt, *Droughts of 1930–1934,* U. S. Geological Survey Water Supply Paper No. 680, Washington, 1936, Plate I and pp. 2–3.

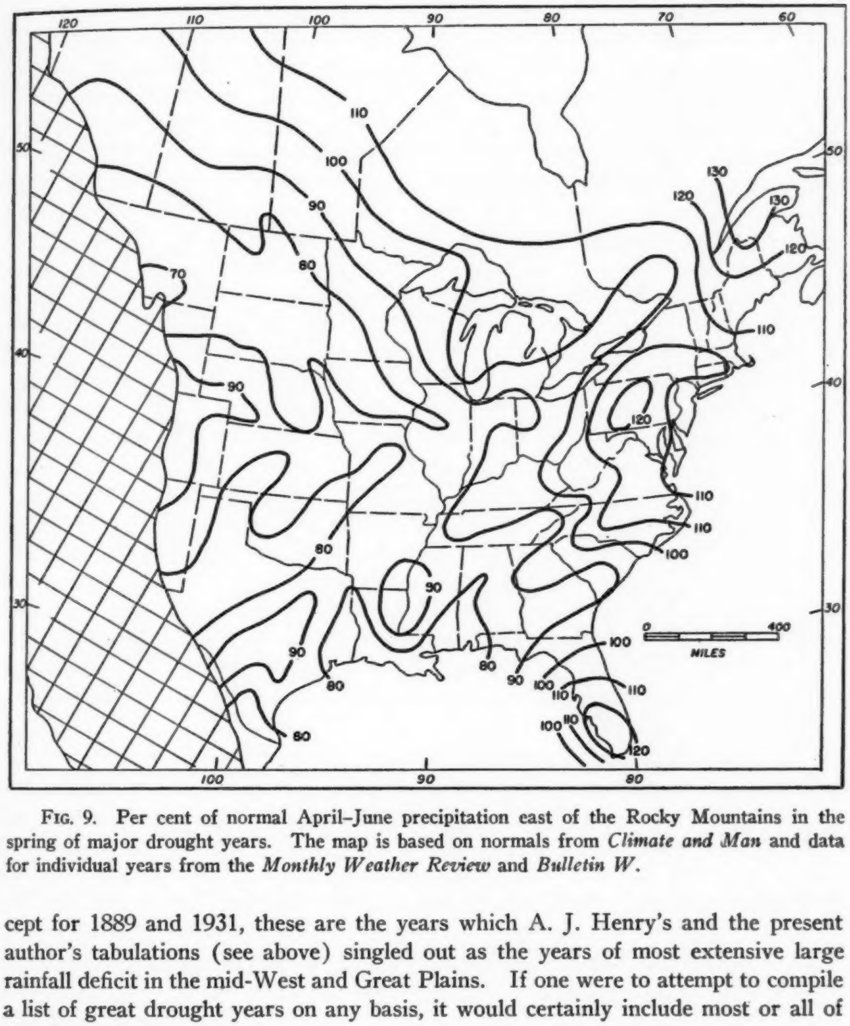

FIG. 9. Per cent of normal April–June precipitation east of the Rocky Mountains in the spring of major drought years. The map is based on normals from *Climate and Man* and data for individual years from the *Monthly Weather Review* and *Bulletin W*.

cept for 1889 and 1931, these are the years which A. J. Henry's and the present author's tabulations (see above) singled out as the years of most extensive large rainfall deficit in the mid-West and Great Plains. If one were to attempt to compile a list of great drought years on any basis, it would certainly include most or all of the above eleven years.

Figure 9 shows the mean April-June precipitation east of the Rockies for these major drought years expressed as a percentage of the 1899–1938 average. Figure 10 shows the mean July-August rainfall east of the Rockies for the same major drought years, again expressed as a percentage of the 40-year mean. From these maps it is clear that in major drought years a great wedge of spring and summer rainfall deficiency has tended to extend from the Great Plains across the mid-West. The wedge has outlined the Grassland most clearly in July and August. In those

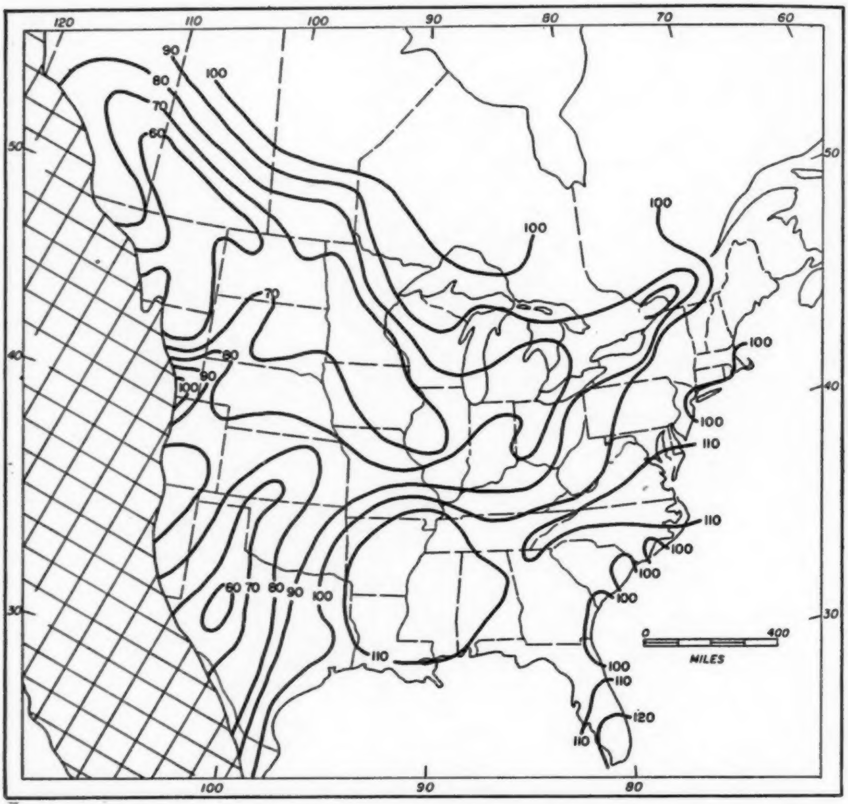

FIG. 10. Per cent of normal July–August precipitation east of the Rocky Mountains in the summer of major drought years. Map based on same sources as Fig. 9.

months there has been an abrupt increase in mean rainfall deficit as one crossed the park margins of the Grassland toward the continental interior. Through April, May, and June the pattern is less clear, and rainfall deficiencies in the Grassland have tended to be generally less than in July and August. In other words, when there has been great drought in the Grassland, the April, May, and June rains have been less likely to fail than the July and August rains. In importance to agriculture this characteristic of the rainfall of the region probably equals or surpasses the more commonly noted mean May-June precipitation maximum in the Grassland. Actually, at many stations in the tall grass prairies July rainfall has exceeded June rainfall in more than half the years of record despite the fact that the June average exceeds the July average. The occasional nearly complete failure of July rainfall in major droughts has created the apparent "normal" May-June peak in the rainfall curves of these stations.

In contrast to the spring and summer deficit of rainfall in the Grassland during major drought years, the summer rainfall in the rest of Anglo-America east of the Rockies has tended to be near or above normal. This has sharpened the regional climatic distinctiveness of the Grassland during those periods. In July 1901, for example, under the heading, "Weather of the Month," the *Monthly Weather Review* said, "The one overshadowing feature of the weather of the month was the long and practically unbroken period of intense heat and drought that prevailed during the month over the great central valleys of the country. The blighting effect of the merciless rays of the sun day after day, supplemented by an almost entire absence of rainfall, threatened the great agricultural regions with ruin so widespread and disastrous as to be scarcely estimated."[18] During the same month rainfall equalled or exceeded the "normal" in New England, the south Atlantic coastal and Gulf states. In July, 1910, the *Review* reported conditions "distinctly tropical" in the Ohio Valley and cloudiness and precipatation greatly in excess of normal in the southeastern states. It also stated that a "prolonged deficiency of precipitation is seriously affecting the vegetation, and the stage of rivers, etc." in the upper Mississippi valley. There was widespread drought in the Grassland that month.[19]

In major drought years the mean rainfall for July has decreased relatively rapidly at the margins of the Grassland (Fig. 11). Within the region the mean precipitation amount tends to be relatively homogeneous. For example, the mean July precipitation in ten dry summers was 1.4 to 1.6 inches at Amarillo, Bismarck, Cheyenne, and Des Moines. That is about 50% of the "normal" at Des Moines, 56% at Amarillo, 64% at Bismarck, and 80% at Cheyenne (Fig. 11). Thus, high plains July moisture-supply conditions overspread all of the Grassland, but precipitation was generally normal or above to the northeast and southeast of the region.

When the summer rains and clouds fail, the mean temperatures soar. If the summer rain fails in the Grassland and not over the forests to the north, the mean temperature gradient along the northern margin of the Grassland tends to increase. In 1936 the entire July mean temperature difference between the lower Rio Grande valley and central Manitoba was concentrated along the northern edge of the Grassland, between extreme northern North Dakota and the forest fringe in Manitoba and Saskatchewan.[20] The weather of that hot, dry July involved a high frequency of winds blowing across the Grassland from the arid western plateaus. The hot winds were usually cut off along the northern edge of the Grassland by cyclonic storms moving along the "Alberta" storm path and along the southeast margin by moist air moving northeastward from the Gulf Coast. Therefore the hot winds were confined mainly to the Grassland and the belt of "oak openings" eastward from the tip of the prairie peninsula. That is usually true. As early as 1894 I. M. Cline pointed out the fact that the "intensely dry" and "hot winds" of the plains are felt occasionally

[18] XXIX, No. 7 (July, 1901), 318–19.
[19] *Monthly Weather Review*, XXXVIII, No. 7 (July, 1910) 1027, 1036.
[20] See *Monthly Weather Review* LXIV, No. 7 (July, 1936) Plate 67.

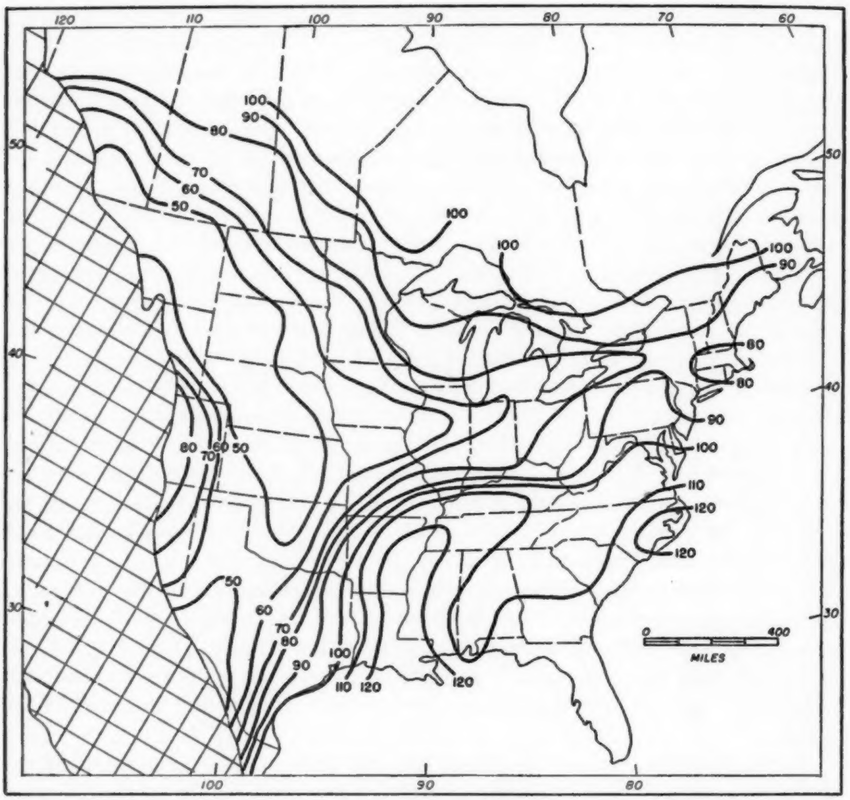

FIG. 11. Per cent of normal rainfall in average July of major drought years. Normals are from *Climate and Man;* data for individual years are from *Monthly Weather Review.*

farther east across the prairie states and even as far east, in the same latitude, as the Atlantic seaboard.[21]

The abnormally high temperatures of dry summers in the Grassland, then, are accompanied by, and are the immediate result of, below-average cloud cover and rainfall and above-average frequency of hot, continental winds. Thus, John K. Rose found in 1936 that there is a high negative correlation between rainfall and temperature in July in the Corn Belt, although at that time there appeared to be "no satisfactory explanation."[22] That this correlation is simply a part of the larger pic-

[21] I. M. Cline, "Summer Hot Winds on the Great Plains," *American Meteorological Journal,* XI, No. 5 (Sept., 1894) 175–86. The same paper appeared in the *Bulletin of the Philosophical Society of Washington,* XII (1894), 335–48.

[22] John K. Rose, "Intercorrelation between Climatic Variables in the Corn Belt," *Monthly Weather Review,* LXIV, No. 3 (March, 1936), 76–82.

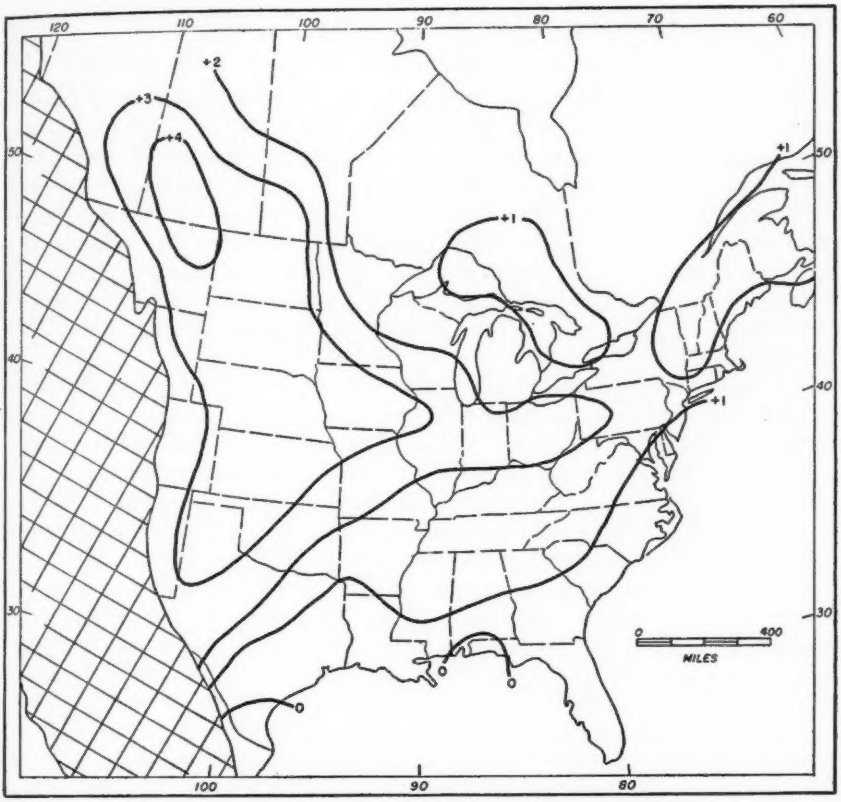

FIG. 12. Average departure from normal temperature in July of major drought years. Sources same as Fig. 11.

ture of subnormal summer rainfall and associated temperature anomalies in the Grassland and its park margins is indicated in Figures 11 and 12.

Up to this point it has been shown that the regional distinctiveness of the Grassland climate lies basically in its precipitation. (1) Low snowfall and low rainfall in in the region are typical of winter. (2) There is a greater risk of a large rainfall deficit in summer within the Grassland than in the bordering regions of forests. (3) The short grass steppe receives markedly less rainfall than the remainder of Anglo-America east of the Rockies during the summer. (4) The Grassland is distinguished from the forested region to the north by fewer days with precipitation, less cloud, and lower relative humidity, on the average, during July and August. (5) The Grassland is characterized by large positive departures from average temperature and by frequent hot winds during dry summers.

THE BASIS OF THE UNIQUE GRASSLAND CLIMATES

The Westerly Circulation and Drought in Central North America

It has been shown that a great drought in Anglo-America east of the Rockies is likely to be most severe in the Grassland. It may be shown, furthermore, that droughts east of the Rockies have tended to occur when, and where, there has been movement of dry, continental air eastward from the base of the Rockies. The farther eastward a flow of this dry air has extended, the farther east the drought has extended. The stronger the westerlies over the United States, the more extensive the drought area east of the Rockies. This has been shown for short periods and for long periods; it is a phenomenon observable in the climatic records for periods of a few days or for many years; and it has been shown in a variety of studies of weather and climate.

There have been numerous investigations bearing upon the relation of circulation and pressure patterns to precipitation in North America.[23] All have brought out one or more of the following facts. (1) An abnormally strong mean westerly circulation for periods of a month, or of several months or more, has been observed to result in subnormal precipitation during the same periods in central North America east of the Rockies. (2) An abnormally strong westerly circulation is associated with a northern hemisphere mean pressure pattern which has the following major features: (a) an abnormally large south-to-north decrease in pressure across the middle latitudes (and, consequently, a strong mean westerly component of the gradient wind); (b) the development of relatively high pressure over the Great Basin and southern plateaus. This pressure pattern is associated with a strong outflow of air from the western Cordilleran region eastward across the Grassland; it is also accompanied by a tendency for moist tropical air entering the United States from the Gulf to turn eastward rapidly as it moves northward, thereby missing the Grassland. (3) An abnormally strong westerly circulation is associated with a high frequency of cylones along the "Alberta" path. The typical "Alberta" low skirts the northern margin of the Grassland west of the Great Lakes and frequently intensifies rapidly over the upper Great Lakes region. South of the typical "Alberta" low west winds blow from the eastern base of the Rockies across the Grassland. Within the cyclone precipitation falls upon the Taiga and northeastern forests. The high frequency of "Alberta" lows and the west winds of the Grassland, to the south of the lows are, obviously, part of the same picture. Persistent westerlies over the Grassland must be associated with persistent low pressure north of the Grassland,

[23] Studies of which pertinent parts are summarized in this section include: J. Namias, *Methods of Extended Forecasting,* U. S. Weather Bureau, 1943, p. 13–15; H. C. Willett, *Descriptive Meteorology,* 1944, p. 143–149; C. G. Rossby, "The Scientific Basis of Modern Meteorology," *Climate and Man* (U. S. Dept. of Agriculture Yearbook) 1941, p. 625–627; R. F. Flint, and H. G. Dorsey, Jr, "Iowan and Tazewell Drifts and the North American Ice Sheet," *American Journal of Science,* CCXLIII, No. 11 (Nov., 1945) 627–636, esp. 629; I. R. Tannehill, *Drought,* 1947, p. 85, 88–113; T. A. Blair, "Two Series of Abnormal Winters," *Monthly Weather Review,* LIX, No. 5 (May, 1931), 175–181; I. M. Cline, "Summer Hot Winds on the Great Plains," *Bulletin of the Philosophical Society of Washington,* XII (1894), 335–348, esp. 346.

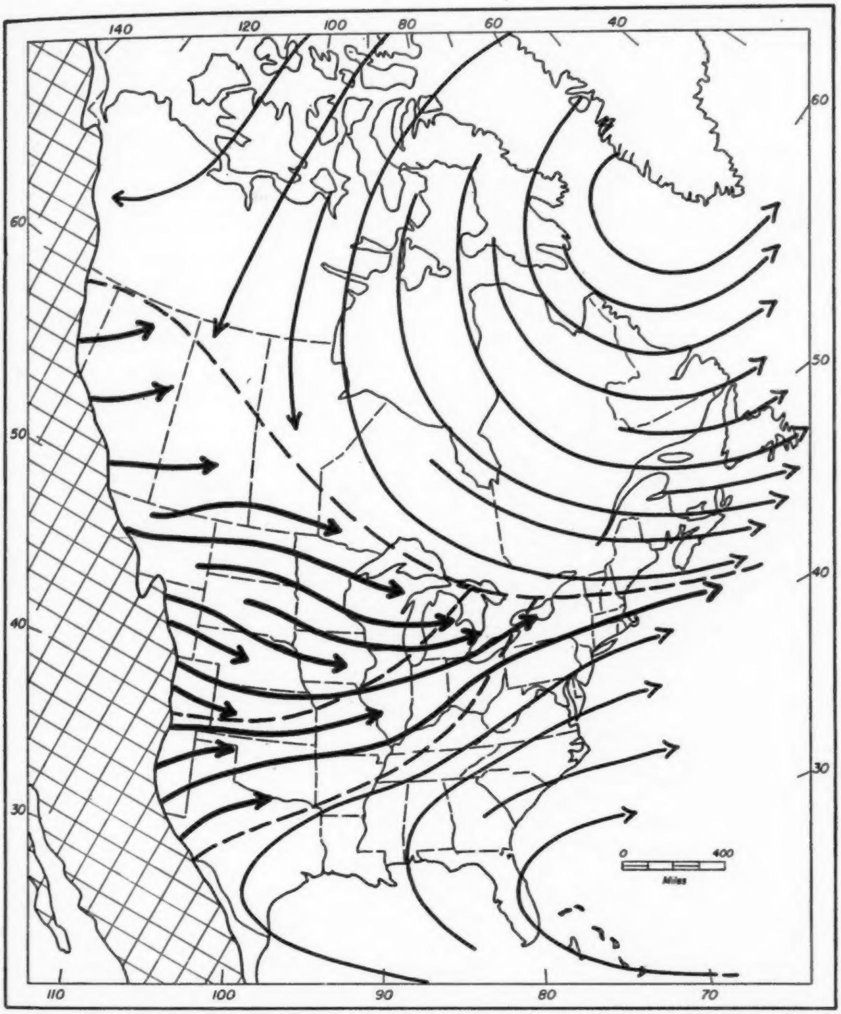

FIG. 13. Streamlines show January resultant mean flow of air across North America east of the Rocky Mountains at gradient level, approximately 1928–1940. Dashed lines are axes of belts of maximum occurrence of low pressure centers on the January surface weather map. Axes from manuscript maps of the number of low centers on the daily weather map (0730 EST) per 30000 square miles in 420 30000-square-mile areas covering North America and adjacent waters, 1930–39. Source of cyclone frequency data: *Historical Weather Maps.*

and vice versa. (4) An abnormally strong westerly circulation is associated with abnormally high temperatures as far east of the Rockies as the continental airflow

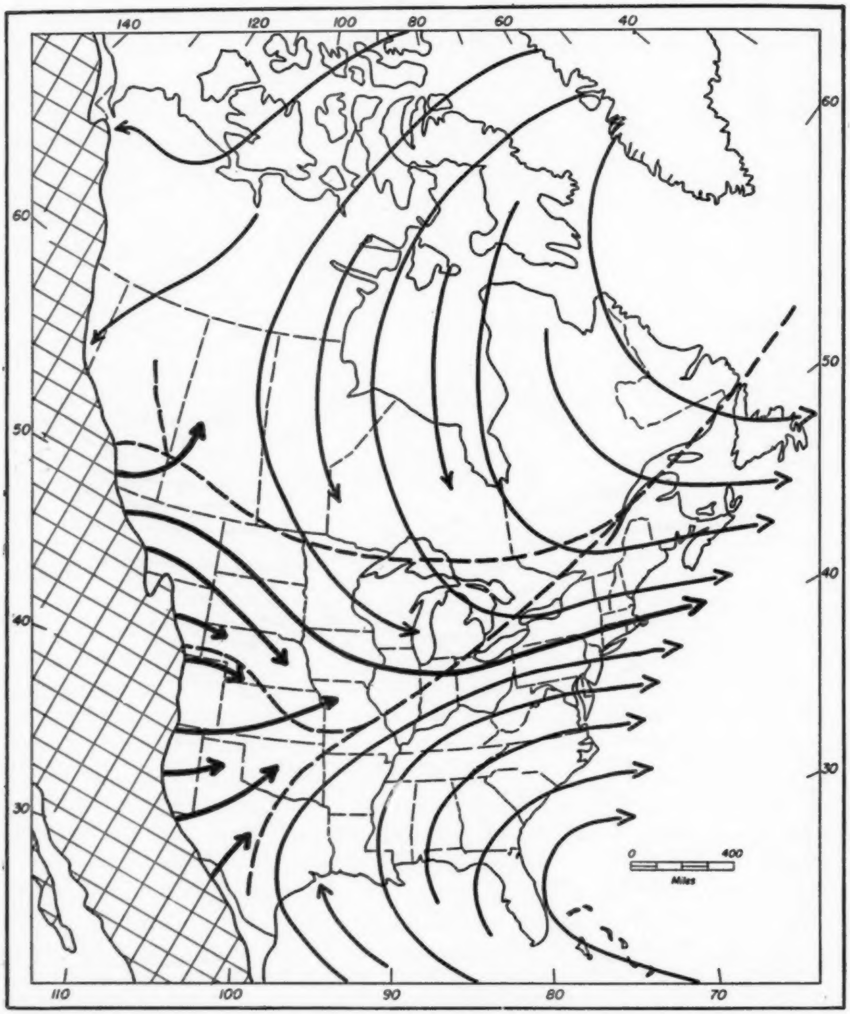

FIG. 14. Streamlines of resultant mean gradient-level airflow and belts of maximum cyclone frequency for March.

from the base of the Rockies prevails because: (a) there is less cloud and rainfall and, consequently, more insolation than normally; (b) there is less injection of cold air from the Arctic into the belt of westerlies.

Thus, periods of abnormally strong westerly circulation tend to be abnormally dry and warm east of the Rockies. The warm, dry area east of the Rockies in dry

periods tends to coincide with the area of the Grassland; this has been shown in the foregoing study of droughts in this paper and will be further elaborated. With these relationships between precipitation east of the Rockies and the strength of the mean westerly circulation in mind, it is now possible to examine the actual mean flow of air over Anglo-America east of the Rocky Mountains.

The Strong Westerlies of Winter

The January mean streamline chart (Fig. 13) shows a strong west-to east flow of air between latitude 35° and 55°.[24] This flow is the middle latitude westerly circulation across Anglo-America. The map also shows three different mean streams of air which flow across Anglo-America east of the Rockies and enter into the general westerly circulation. These different mean streams come from three different centers of mean divergence: the sub-tropical Atlantic anticyclone, the Arctic region, and the eastern base of the Rockies.

The stream moving eastward from the base of the Rocky Mountains has crossed a series of major orographic barriers, subsided over the Great Basin and interior plateaus,[25] and descended to the Great Plains. It is a dry, *continental* stream of air. This mean continental flow is carried far to the east in the strong westerlies of winter. It occupies a wedge extending across the Grassland and eastward through the Great Lakes region in January (Fig. 13). The continental wedge lies between two belts

[24] Figures 13, 14, 15, and 16 show the mean monthly movement of air, representative of different seasons, at the gradient level (about 500 meters above the surface). The flow is shown by streamlines drawn to resultant winds at 102 places east of the Rocky Mountains for a period approximately 1926–1940.

Resultant winds from the level 500 meters above the surface were chosen for these maps for several reasons. The 500-meter level is far enough above the surface to eliminate most peculiarities of wind direction resulting from local orography. On the other hand, that level is low enough to provide maximum accuracy and regularity of pilot balloon observations. It is also near enough to the surface of the earth to permit the assumption that horizontal convergence and divergence are compensated by vertical ascent and descent, respectively, in the overlying atmosphere. Finally, it is low enough to be representative of the general flow of air in which life at the earth's surface exists.

Data are from unpublished resultant winds computed in the Division of Hydrologic and Climatological Services, U. S. Weather Bureau. The use of streamlines drawn to wind data is a common device which could be put to more use as a visual aid in explaining regional differences in climate. For examples see V. Conrad, *Methods in Climatology,* 1944, p. 190; Thos. R. Reed, "The North American High Level Anticyclone," *Monthly Weather Review,* LXI, No. 11 (Nov., 1933), 321–325; Chang-Wang Tu, "A Preliminary Study on the Mean Air Currents and Fronts of China," *Memoirs of the National Research Institute of Meteorology,* XI No. 3 (Sept., 1937), 1–10, maps (monthly streamlines over China).

[25] U. S. Weather Bureau resultant wind data indicate the importance of mean winter subsidence in the region between the Pacific coast and the eastern base of the Rocky Mountains. During the average January, between the surface and three kilometers above sea level in the United States, the amount of air that moves east from the eastern base of the Rockies is about three times as great as the amount of air which moves eastward against the Coast Ranges and the Sierra-Cascade Ranges. This divergence below the three-kilometer level must be compensated by mean vertical descent from above the three-kilometer level.

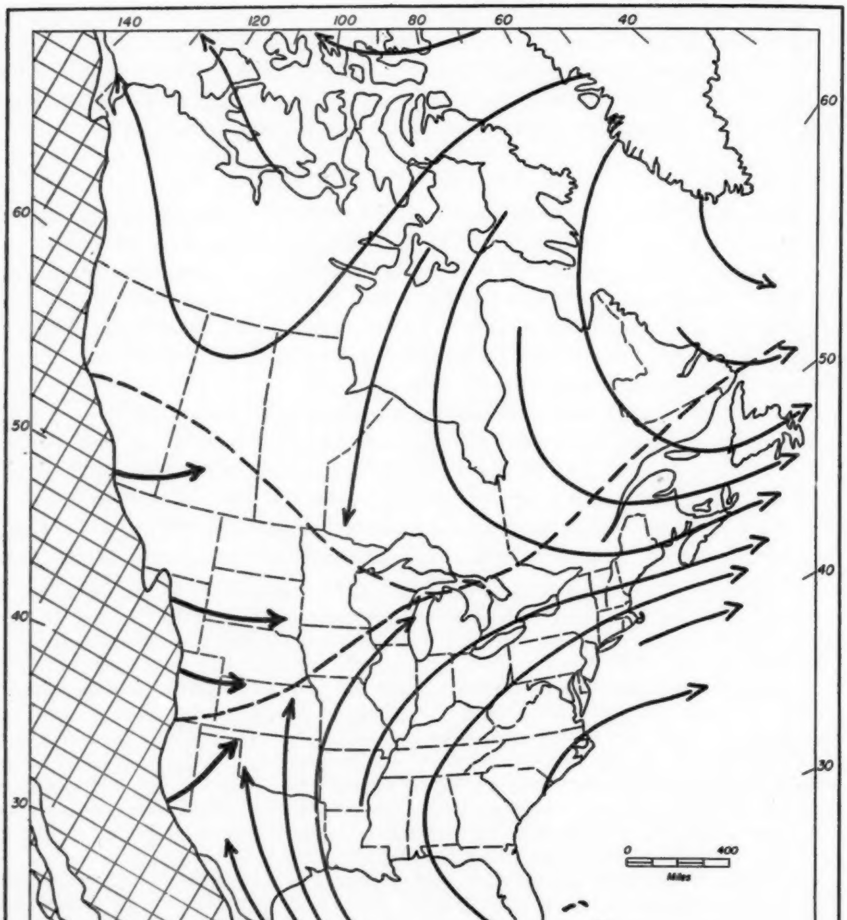

FIG. 15. Streamlines of resultant mean airflow at the gradient level and axes of belts of maximum cyclone frequency for May.

of maximum cyclone frequency focusing on the lower Great Lakes region, one from Alberta and the other from Texas.[26] This wedge of continental air is approximately coincident with the Grassland and its bordering parklands. The stream undergoes the most cyclonic convergence along the northern margin of the wedge where it is

[26] See Jerome Namias, *op. cit.*, 54.

led into the Alberta storm path. This accounts for the increase in snowfall across the northern edge of the Grassland (Fig. 4).

A second distinct mean air stream on the January chart moves southward from the Arctic ice cap (Fig. 13). It is a cold, dry *Arctic* flow. It dominates the region north of the Alberta storm belt. Consequently that region has persistent freezing temperatures and a continuous snow cover in winter (Fig. 4).

The third distinct mean airstream moves from the *tropical Atlantic* Ocean westward and northward across the Gulf of Mexico. In winter this stream is confined, in Anglo-America, to the southeastern United States (Fig. 13). This stream undergoes frequent cyclonic convergence southeast of the Grassland, where it flows into the "Texas" storm path. This accounts for the marked increase in winter rainfall along the southeastern margin of the Grassland. These same mean airstreams and mean source regions—continental, Arctic, and tropical Atlantic—are distinct on the streamline charts for all other months, as well as January; and they account for all of the mean air transport across the continent east of the Rocky Mountains.[27]

In March (Fig. 14) the pattern is similar to January, but the wedge of continental air has contracted slightly. The mean flow of air eastward from the Rockies is weaker in March than in January. This accompanies the weakening of the normal winter high pressure over the Great Basin. Thus the typical wedge of low snowfall and low rainfall over the Grassland in winter is associated with a strong mean west-to-east continental airflow east of the Rocky Mountains and with the position of the region between the major storm paths.[28]

The Weak Westerlies of Summer

The Alberta storm belt remains in approximately the same position in summer as in winter (Figs. 13, 16); and the region to the north of it continues to be distinguished by a mean Arctic airflow. To the south of the Alberta track, however, there is a marked decrease in the west-to-east component, and an increase in the south-to-north component of the mean airflow across the United States. Consequently, the dry continental airstream is confined during the summer to the short grass region west of approximately the 100th meridian, and south of the Alberta storm path (Fig. 16). On the other hand, the tropical Atlantic airstream, which flows across the southeastern United States in winter, penetrates farther into the continent in summer. During April, May, and early June it displaces the continental stream everywhere south of the Alberta storm path and east of the 100th meridian (Fig. 15). It continues over that area through July (Fig. 16) and August.

[27] The three mean-airmass names introduced in the foregoing paragraphs will be used throughout the remainder of this paper wherever airflow is discussed in connection with climatic means. The three terms describe the major mean airmass differences in eastern America in terms of source regions which appear on the maps of mean airflow. The common meteorological airmass terminology (i.e., Willett or Bergeron) will not be used.

[28] This precipitation and circulation pattern has recently been outlined by W. H. Klein, "Winter Precipitation as Related to the 700-Millibar Circulation," *Bulletin of the American Meteorological Society,* XXIX, No. 9 (Nov., 1948), 439–453, esp. 450–452 and Fig. 12.

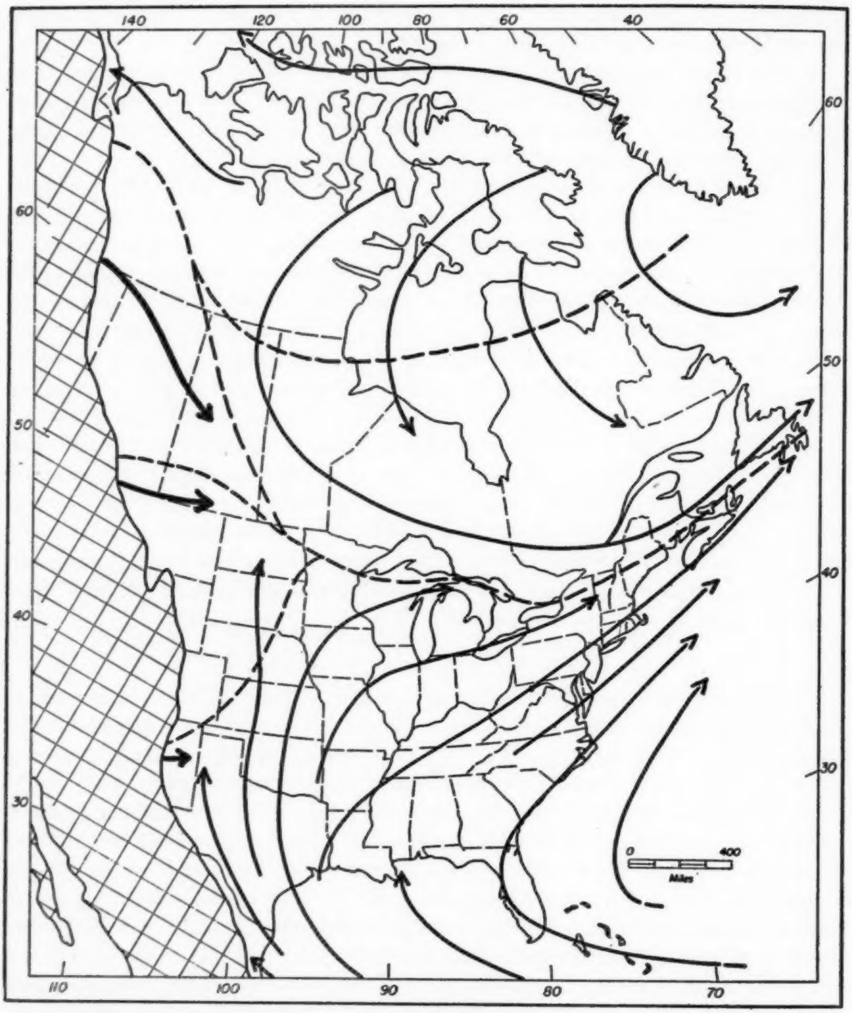

FIG. 16. Streamlines of resultant mean airflow at the gradient level and axes of belts of maximum cyclone frequency for July.

Therefore, the sharp eastward decrease in summer rainfall across the 100th meridian (Fig. 5) is associated with the same mean airmass difference as the steep winter rainfall gradient across the southeastern edge of the prairies (Fig. 3). Furthermore, the change from a mean continental to a mean tropical Atlantic stream eastward across the 100th meridian explains the coincident rapid increase in summer

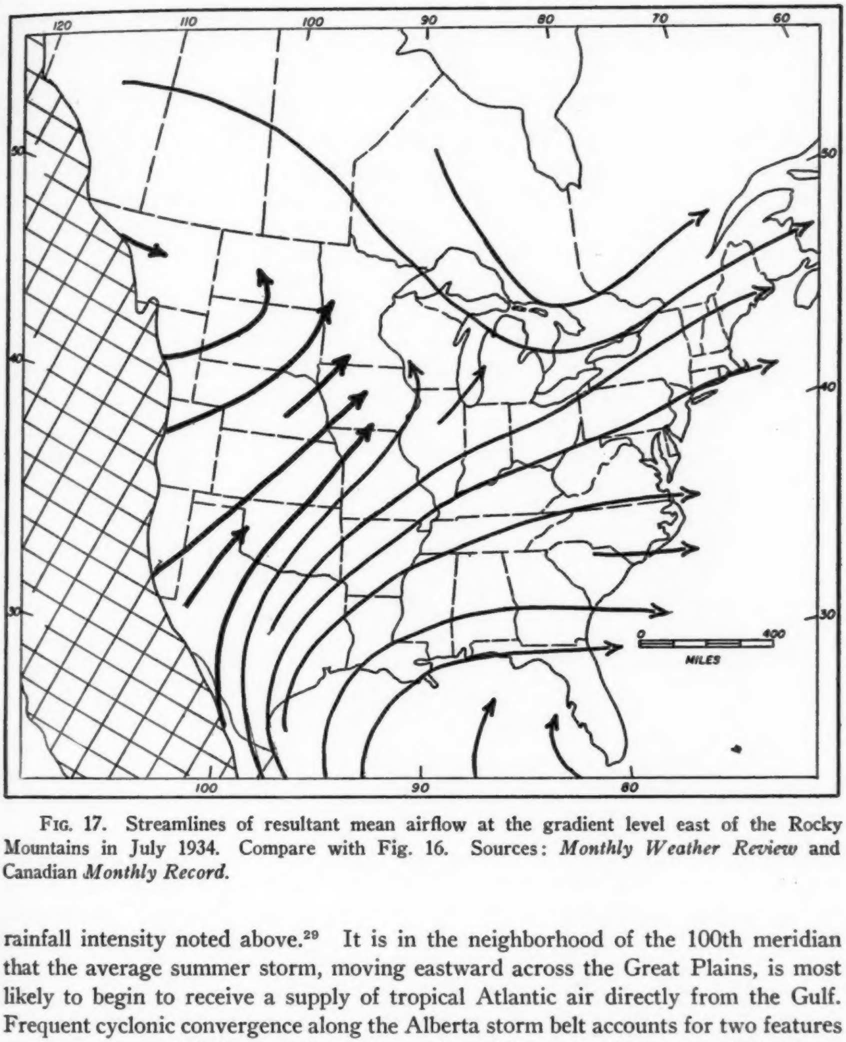

FIG. 17. Streamlines of resultant mean airflow at the gradient level east of the Rocky Mountains in July 1934. Compare with Fig. 16. Sources: *Monthly Weather Review* and Canadian *Monthly Record.*

rainfall intensity noted above.[29] It is in the neighborhood of the 100th meridian that the average summer storm, moving eastward across the Great Plains, is most likely to begin to receive a supply of tropical Atlantic air directly from the Gulf. Frequent cyclonic convergence along the Alberta storm belt accounts for two features on the summer rainfall maps; first, the northward increase of summer rainfall from the steppe in Montana to the forest in southern Alberta and Saskatchewan (Fig. 5)

[29] Because the precipitation gradient across the Great Plains is so steep, relatively slight changes in the general circulation during the summer can produce relatively large departures from the average rainfall within that gradient zone. Henry M. Kendall has pointed out the importance of these year-to-year fluctuations; see "Notes on Climatic Boundaries in the Eastern United States," *Geographical Review,* XXV, No. 1 (1935), 117–124.

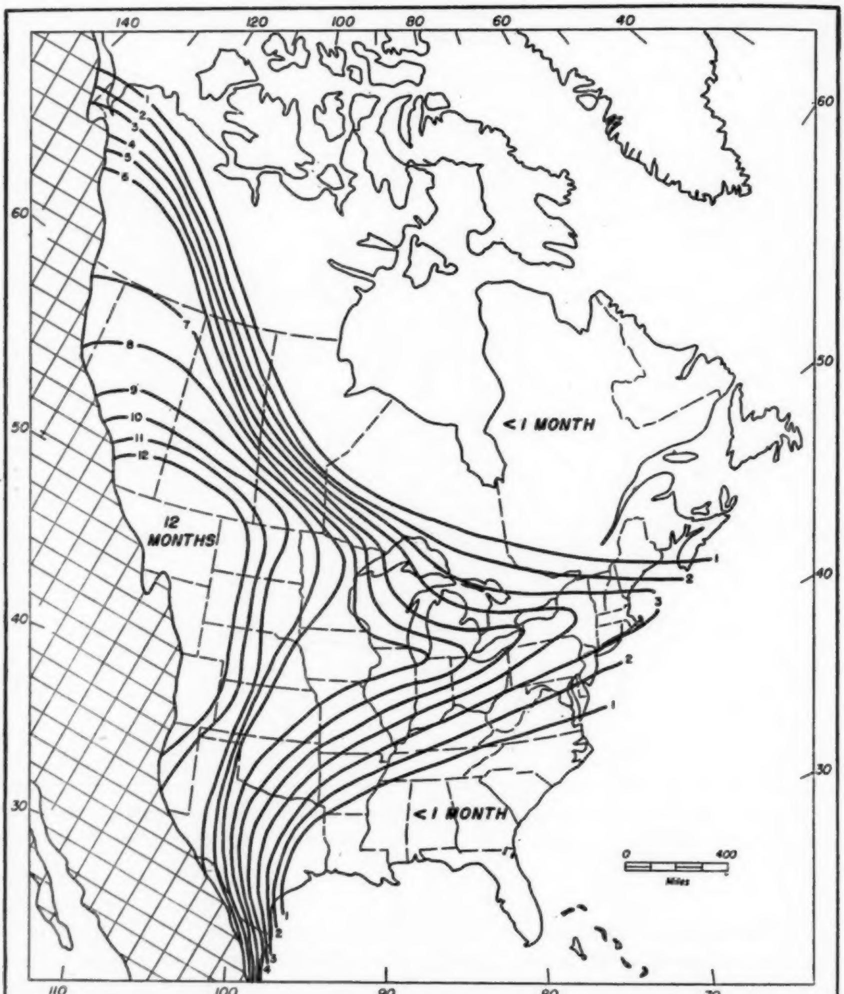

FIG. 18. Average number of months per year with a mean transport of air from the eastern base of the Rocky Mountains. Compiled from manuscript maps of monthly mean resultant airflow, including those reproduced in Figs. 13, 14, 15, and 16.

and, second, the increase in average number of days with rain which occurs to the north of the Grassland (Fig. 6).

Thus the increase in summer rainfall over the prairie portion of the Grassland results from a decrease in the strength of the mean westerly circulation south of the Alberta storm belt. The continental air stream does not dominate the middle-

latitude circulation as far eastward from the Rockies in summer, when the westerlies are weak, as it does in winter, when the westerlies are strong.

The Stronger Westerlies of Dry Summers

The mean tropical Atlantic airflow that covers the Grassland east of the 100th meridian in normal summers has tended to give way during the summers of major drought years to a continental flow. In other words, the flow across the Grassland has been more westerly than normal (Table I). This has been accompanied by a general tendency toward the normal winter pressure pattern and away from the normal summer pattern over much of the United States. Mean (sea level) pressure in summers of major drought years has tended to be higher than normal over the southern and western parts of the interior basins and plateaus. The south-to-north pressure gradient has tended to increase; thus the mean gradient wind direction across the country has tended to become more westerly.[30] An example of the tendency away from the normal and toward a more continental flow of air across the Grassland occurred in July, 1934, when drought was widespread in the mid-West and Great Plains (Fig. 17).

TABLE I

West-to-East Component of Summer Resultant Gradient Winds at Omaha (meters per second)

	April–June	July–August	April–August
Mean (1918–1938)	+0.05	−0.52	−0.18
Mean of Major Drought Yrs.*	+0.26	+0.28	+0.26

* 1930, 1931, 1933, 1934, 1936. Sources: Unpublished resultant wind data from U. S. Weather Bureau; resultant winds published in the U. S. *Monthly Weather Review.*

The Region of Continental Airflow East of the Rockies

Normally there is a monthly continental airstream at the gradient level over the western part of the Great Plains between northern New Mexico and southern Alberta throughout the year (Fig. 18). The remainder of the Grassland has a continental flow during at least half the year. The number of months per year with a mean continental flow declines rapidly, in favor of an Arctic flow, across the Alberta storm path at the northern margin of the Grassland and, in favor of a tropical Atlantic flow, across the Texas storm path at the southeastern margin. The wedge of mean "airmass continentality" extending eastward to the lower Lakes region results from the period of strong mean westerlies during winter. Thus the influence of continental air upon the climate extends farthest east in the latitude of strongest mean westerlies. In 1934—a year of major drought—there was a continental airflow across the Grassland during every month of the year (Fig. 19). Continental air from the southwest displaced the normal summer tropical Atlantic flow from the south over the prairie peninsula.

[30] Manuscript maps prepared for this study, but not included in this paper show that the greatest increase in the south-to-north pressure gradient occurred west of the central Great Plains, in Utah, Colorado, and southern Wyoming.

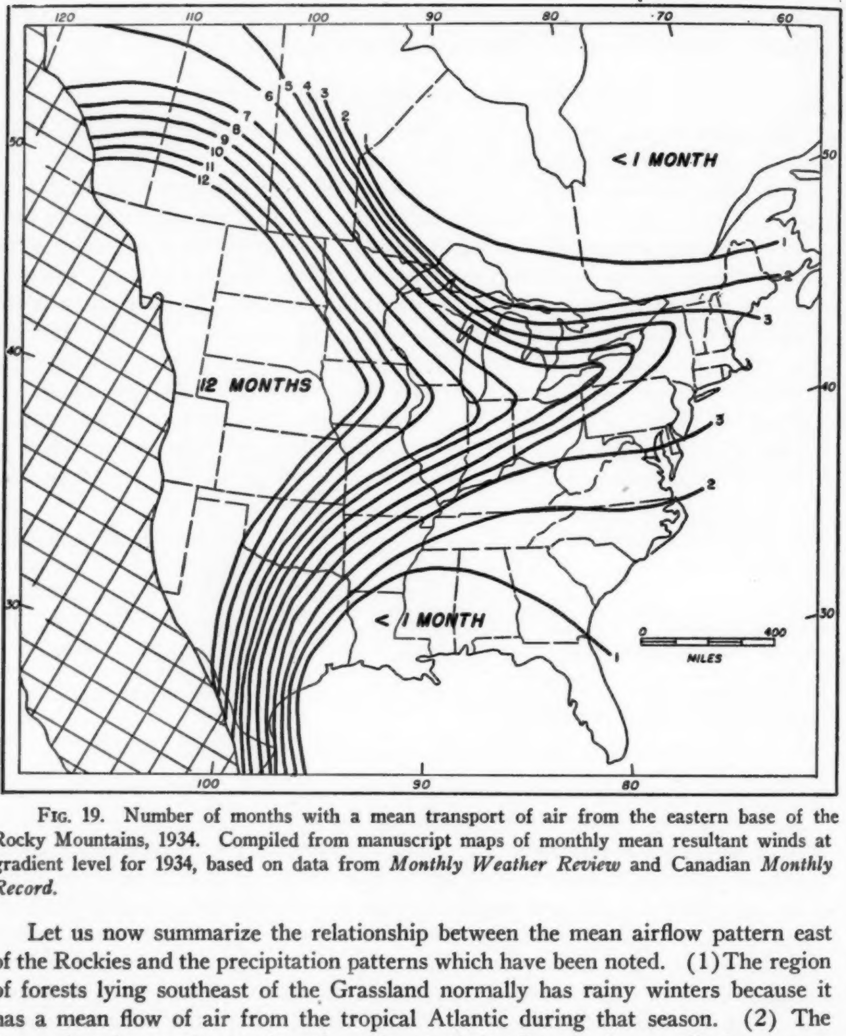

FIG. 19. Number of months with a mean transport of air from the eastern base of the Rocky Mountains, 1934. Compiled from manuscript maps of monthly mean resultant winds at gradient level for 1934, based on data from *Monthly Weather Review* and Canadian *Monthly Record.*

Let us now summarize the relationship between the mean airflow pattern east of the Rockies and the precipitation patterns which have been noted. (1) The region of forests lying southeast of the Grassland normally has rainy winters because it has a mean flow of air from the tropical Atlantic during that season. (2) The forested region to the north and northeast of the Grassland normally has snowy winters because of precipitation from storms along the Alberta storm path and the persistent flow of air from the Arctic across the region. (3) The summer rains of the prairies result from the change from a continental to tropical Atlantic airflow during the warm season. (4) The low rainfall of the western short grass steppe during the summer results from the persistence there of a mean continental airflow. (5) In the summers of major drought years in the Grassland, the normal southerly

flow of air from the Gulf has failed, and the mean airflow has been from the hot, dry interior of the continent. Thus the basis for the Grassland's climate may be found, as one should expect, in the pattern of the general circulation of the atmosphere together with the orography and position of the North American Continent in the belt of westerlies. Those are the major genetic factors in the North American climate.

The unique climates of the Grassland occupy a wedge-shaped region because of their unique position on the North American continent in the belt of westerlies. Between central Alberta and south Texas the middle-latitude westerlies descend from a major orographic barrier upon the great continental plain of North America. Hence there is a dry climate at the eastern base of the Rockies, in the western Great Plains. The mean tropical Atlantic and Arctic airstreams have access to the zone of westerlies without orographic interruption only east of the Rocky Mountains, on the North American plain. Tropical Atlantic air enters the middle latitudes in an anticyclonic path from the south; Arctic air enters in a cyclonic path from the north. The stronger the mean westerly circulation in the middle latitudes, the farther eastward the entering Arctic and tropical airstreams are carried before they converge. Consequently the more elongate is the dry continental wedge that extends eastward from the Great Plains. When the low precipitation that is characteristic of the Great Plains spreads eastward during a season or during a long period of years, it may be expected to do so in a wedge-shaped area (Fig. 10). The size and shape and degree of dryness of the wedge stems from—and would be altered by any change in—the shape and relief of the North American landmass and the strength of the mean westerly circulation.

SUMMARY OF THE CLIMATIC REGIONALISM OF THE GRASSLAND DURING THE PERIOD OF CLIMATIC RECORD

The Nature of the Climatic Boundaries

It has been noted that the climate of the Grassland is relatively homogeneous in terms of (1) its low winter rainfall and snowfall, (2) the occasional major droughts in summer and the tendency for major summer droughts to occur synchronously within the region, and (3) the continental source and trajectory of the mean airstream which blankets the region during dry periods. The regional climatic homogeneity of the Grassland lies basically in its precipitation and in the mean airmass characteristics which explain the precipitation patterns. The definition of this or any other region of relatively homogeneous climate on an interior plain must be in terms of precipitation and closely related phenomena, such as cloud cover. This becomes apparent if one considers the causes of relatively rapid changes in climate from place to place.

A rapid steepening of mean temperature gradient is not likely to occur except across a coast line or in a highland region where there are rapid changes of orographic gradient. On a continental plain, such as that occupied by the Grassland,

the two factors of land-water difference and relief are eliminated. The dominant remaining factor controlling temperature is latitude (insolation). This produces simply a relatively even south-to-north gradient of mean temperature. Mean isotherms are deflected somewhat from the parallels by differences in the direction of the prevailing winds. Where prevailing winds blow across the parallels, mean isotherms tend to shift northward or southward with the prevailing flow of air. However, an airmass moving meridionally is constantly being subjected to the effects of increasing or decreasing insolation; and its temperature is changing accordingly. Latitude is the chief control of mean temperature and associated aspects of the climate, such as growing season, where there are no marked regional differences in surface or elevation. Therefore no interior plain region can have relative climatic homogeneity in terms of any mean temperature values if that region has appreciable latitudinal extent. This is illustrated by all climatic regions which climatologists have delineated.

Mean precipitation gradients in contrast to temperature gradients, can exhibit sharp regional differences on an interior plain such as that of North America. Specific examples of this have been noted in the preceding section of this study, and it has been shown that the precipitation gradients are the result of regional differences in the source and trajectory of the prevailing airflow and the mean amount of convergence. Where there are no great regional differences in relief or elevation and no coast line, regional differences in the circulation of the atmosphere may be expected to control the regional pattern of precipitation and, therefore, the regional pattern of climate.

One exception to the rule just stated should be cited. That is the isotherm of 32° F—the critical temperature of water. That is the one temperature value which is definitely known to be critical to a particular element in the physical geographic environment regardless of the time, place, or specimen chosen. The relatively rapid south-north change from rainy winters to snowy winters which characterizes the belt from northern Illinois eastward to the southern New England coast is clearly related to the 32° isotherm. The difference between snowy, frozen winters and rainy winters must have far-reaching effects upon the surface of the land which remain to be studied and expressed quantitatively by physical geographers. Consideration of the foregoing ideas alone justifies Köppen's belief—and Russell's recognition of the possibility—that the criterion of cold-season temperature for a major climatic boundary (C-D) loses validity in dry climates.[31] The critical temperature of water in determining regional precipitation differences becomes less important when there is less precipitation. The significance attached by Köppen to persistent snow cover,[32] as well as Ackerman's choice of 32° F. as a major climatic

[31] R. J. Russell, "Dry Climates of the United States, I," *University of California Publications in Geography,* V, No. 1 (Jan., 1931), 27.

[32] W. Köppen, *Grundriss der Klimatologie,* Berlin, 1931.

boundary—in the Köppen framework—in the eastern United States,[33] is likewise justified.

On an interior plain regional differences in mean precipitation are necessarily superimposed upon a field of gradual and relatively uniform poleward mean temperature gradients. Consequently there are places where both mean temperature and mean precipitation gradients are slight. Those may be considered areas of relatively homogeneous climate. On the other hand, there are zones across which the mean precipitation gradient steepens rapidly, although the temperature gradient does not change. These zones are more than zones of steep precipitation gradients; they are zones of steep climatic gradient. Where one climatic element changes rapidly from place to place while others continue to change slowly, the result is necessarily a relatively rapid change in the sum of the climatic elements—the climate. This point is well illustrated in the Great Plains states. When a Kansan says that there is a big difference in the climate of eastern and western Kansas, he means that in his experience there has been a great difference between the two ends of the state in the amount of rainfall and the number of heavy rains during the summer. That great difference in summer rainfall is synonymous with a great difference in climate. The difference during the summer season leaves its impression upon many elements of the landscape which are present throughout the year. The farms in western Kansas look different from those in eastern Kansas to a very large degree because the western Kansas farmer has to expect a very different kind of *summer* climate from that which is most likely in eastern Kansas. That simple fact is obscured when we express the east-west climatic gradient across Kansas in terms of a numerical combination of mean *annual* temperature and precipitation.

If its distribution is causally related to climate, any element in the landscape may be expected to change relatively rapidly where the climate changes relatively rapidly. Consequently one could expect to find a regional pattern in the distribution of natural vegetation which corresponded to the regional pattern of climates. One might also expect the regional vegetation pattern to be superimposed upon a field of gradual south-to-north change, just as the regional pattern of climate is superimposed upon a gradual poleward mean temperature gradient.[34]

In view of the foregoing considerations, it is not surprising that the present study discloses that the climatic gradients across the Grassland boundary are in values of precipitation and closely related phenomena.

[33] Edw. A. Ackerman, "The Köppen Classification of Climates in North America," *Geographical Review,* XXXI, No. 2 (Apr., 1941), 105–111.

[34] This idea has also been suggested by Malin following his extensive review of the existing literature on the ecology of the Central Great Plains grasses by Schaffner. See James C. Malin, *The Grassland of North America,* 1947, pp. 80 and 398; and J. H. Schaffner, "Observations on the Grasslands of the Central United States," *Ohio State University Studies* (Contributions in Botany) 178 (1926), 1–56. Kendall has pointed out the importance of considering climatic *gradients* rather than static climatic boundary *lines.* See Henry M. Kendall, *op. cit.,* esp. pp. 117 and 123.

A corollary to the proposition outlined above may be pointed out. If one attempts to combine mean temperature and mean precipitation values to express the moisture budget the resulting regional pattern on a continental plain must resemble the regional pattern of moisture supply, or precipitation. A comparison of Thornthwaite's map of theoretical potential evapotranspiration and his map of moisture index shows this clearly.[35] The calculation of potential evapotranspiration is based upon mean temperature and latitude. Consequently, on the interior plain of North America, away from the Gulf and Arctic, there are no marked regional differences in the gradient of potential evapotranspiration. However, there are zones of rapidly steepening gradients of moisture index.[36] The moisture index is a combination of theoretical water need (potential evapotranspiration) and supply (precipitation). Since there are no marked regional differences in the gradient of theoretical water need, a rapid change of gradient of the moisture index must result from a rapid change of precipitation gradient. Thus, one should be able to arrive at Thornthwaite's regional pattern of moisture index by a study of regional differences in precipitation. As far as the Grassland is concerned, it is clearly possible to do just that. It should be emphasized, however, that the present discussion deals with the problem of delineating climatic regions, and not with the problem of classifying series of climatic statistics or calculating hydrologic data from meteorological observations.

The Position of the Grassland in the Climatic Regions of Eastern America

On the basis of the regional differences in climate which appear on the maps in the first section of this study it is possible to delineate five major climatic regions in eastern America. These regions are outlined in Figure 20; and their distinctive climatic features are discussed briefly below.

I. The Northeastern region is characterized by snowy winters (Fig. 4). Most of the snow that falls on the North American continent east of the Rockies falls in this region. Summers are usually free from severe, protracted drought. Thus deep winter snow and reliable summer rains are the features which set off the climate of this region.

II. The southeast and eastern seaboard has rainy winters; most of the winter rainfall of Anglo-America east of the Rocky Mountains occurs in this area (Fig. 3). The region receives as much or somewhat more rain in summer than in winter, but summers are sunnier. Winter, because of its high rainfall is the season during which the region is climatically distinctly different from the rest of eastern America. From its distinctive winter climate arise at least two major problems in the region's use—soil erosion and flood control.

III. The south Atlantic and Gulf coasts have rainy tropical summers. The May-August rainfall in this region averages about fifty per cent more than that over

[35] C. W. Thornthwaite, "An Approach Toward a Rational Classification of Climate," *Geographical Review*, XXXVIII, No. 1 (Jan., 1948), 55–94.

[36] *Ibid.* Figures 5, 6, Pl.A.

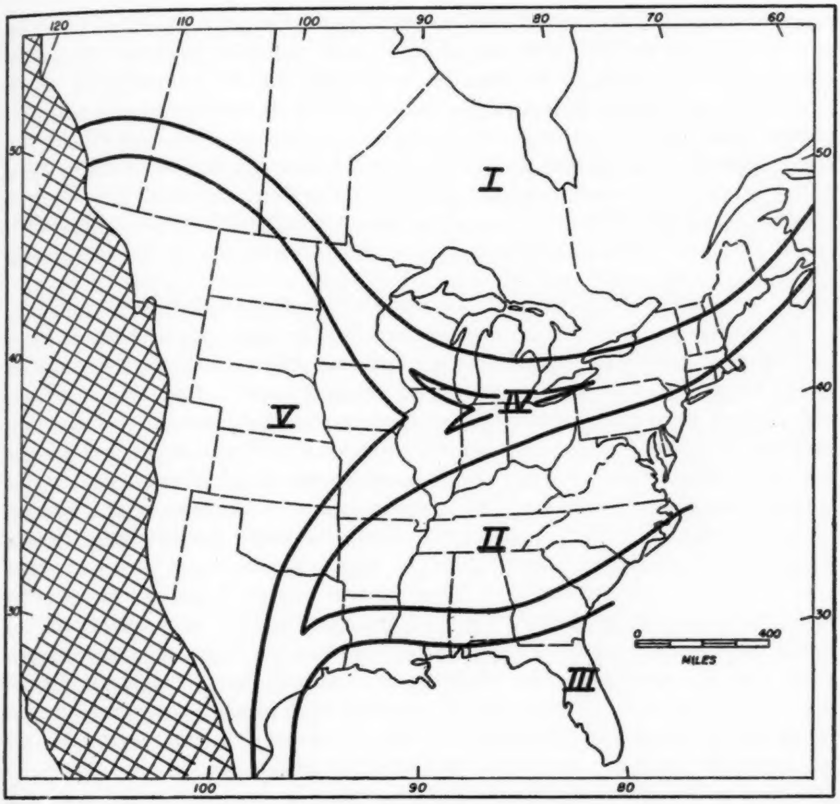

FIG. 20. Climatic regions of eastern America.

the rest of the eastern United States. The gradient of mean summer rainfall separating the region from the rest of the country is one of the steepest—on a plain—in the world (Fig. 5). The question of the degree of relationship between the northern margin of this climatic region and the southern margin of the cotton belt or the northern margin of the coastal plain pine forest merits investigation.

IV. The Prairies usually have relatively dry winters and occasionally have a low summer rainfall similar to that typical of the western Great Plains. The details of this climate and of the climate of Region V have already been discussed.

V. The western Great Plains—the short grass steppes—have relatively dry winters and summers. The region lies near the foot of a steep summer rainfall gradient. (Fig. 5).

Except for the prairies the regions outlined in Figure 20 are similar to the major climatic subdivisions of eastern America according to the Köppen classification of

climates. Region I suggests the D climates; region II suggests the C climates; region III suggests the A climate; and region V suggests the BS climates. This coincidence appears to support the idea that, in general, the Köppen categories of climate are founded upon climatic regions which have a genetic basis and which have internal similarity in terms of their precipitation and related elements. The climatic distinctiveness of each of these regions, and its significance in the physical and cultural geography of the regions are subjects for further investigation.

The Grassland, it may be repeated, occupies two of these climatic regions—IV and V (Fig. 20). It has a unique position in the climatic regions of eastern America.

WILD VEGETATION AND THE RECORDED GRASSLAND CLIMATES

A large body of observations has indicated ways in which the wild vegetation of the Grassland reflects the regional climatic pattern. In the short grass steppe (Region V, Fig. 20) relatively dry winters and summers result in frequent depletion of soil moisture during the growing season to the point where there is no longer any available for plants.[37] Not only are the short grasses of the steppe well-adapted to these moisture conditions, but also because of their dense, fibrous, shallow root systems they are well able to utilize the summer rains of low intensity.[38] Furthermore, the thin and often absent snow cover in the north permits deep freezing. That increases the risk of "winterkilling" of trees by desiccation in strong wind and very dry air at low temperature.[39] Thus Aikman has noted the lack of indication of any natural forest invasion of the short grass steppe away from the stream valleys of the region.[40] On the other hand there has been no observed natural invasion of the area by desert shrub from its dry western margin except during the drought years of the 1930's. And that trend was reversed when precipitation increased again in the last three years of the decade.[41] Thus it appears that this region has a climate to which grass is better suited than forest or desert shrub.

The climatic region coincident with the prairies (Region IV, Fig. 20) is actually a broad boundary zone between steppe and forest. In the climate of the prairie region forests have a better chance of survival than in the steppe. On the other hand, grass is better adapted to the low winter rainfall, unreliable snow cover, and occasional severe summer drought of the region.

[37] J. E. Weaver, and A. F. Thiel, "Ecological Studies in the Tension Zone between Prairie and Woodland," *University of Nebraska Botanical Survey,* (New Series) I (1914), 1–59; C. L. Forsling, "Snow Melt," in *Climate and Man,* Washington, 1941, pp. 557–560.

[38] R. D. Lane, and A. L. McComb, "Wilting and Soil Moisture Depletion by Tree Seedlings and Grass," *Journal of Forestry,* XLVI, No. 5 (May, 1948), 344–349; F. W. Albertson, and J. E. Weaver, "Injury and Death or Recovery of Trees in Prairie Climate," *Ecological Monographs,* XV, No. 4 (1945), 395–432.

[39] See John W. Bews, *The World's Grasses,* London, 1929, p. 308; W. E. Brunner, "The Vegetation of Oklahoma," *Ecological Monographs,* I, No. 2 (April, 1931), 121.

[40] J. M. Aikman, "Native Vegetation of the Region," in *Possibilities of Shelterbelt Planting in the Plains Region,* Washington, 1935, p. 158.

[41] Lincoln Ellison, and E. J. Woolfolk, "Effects of Drought on Vegetation near Miles City, Montana," *Ecology,* XVIII, No. 3 (July, 1937), 329–336.

Differences have been observed between the effects of the prairie and steppe climates upon wild vegetation. The tall grass association is typical of the prairie and distinctly different from that of the steppe. Establishing successful farm shelter-belts has been much less difficult in the tall grass region than in the short grass country to the west. Furthermore, considerable evidence has been presented recently to show that the prairie peninsula, in undisturbed places, has undergone a very gradual natural forest invasion through the past seven or eight centuries to the present time.[42] Although this natural spread of forests has been very slow, it is in contrast to the conditions in the short grass region.

On the other hand there is evidence that the prairie climate has been more hostile to tree growth than the climates of the surrounding forests. For example, Transeau noted the death of thousands of oaks bordering the prairies in Illinois in the drought of 1910.[43] Albertson and Weaver reported the widespread desiccation and death of forests and planted groves in the 1930's in eastern Nebraska.[44] McComb and Loomis noted the death of, or severe damage to, ". . . hundreds of thousands of adapted trees on suitable or even protected sites . . ." during the same period in Iowa.[45] There was no such wholesale damage to woodlands outside the Grassland. During the dry years of the 1930's prairie grass associations moved into the areas where trees perished. Also, the short grass association displaced tall grass in the prairies of Iowa, Kansas, and Nebraska, and retreated again as the rainfall increased at the end of the decade.[46]

The record supports the statement by McComb and Loomis that the ". . . climate of the region (the prairie) is clearly borderline between the forest and the grassland climax."[47] It has already been noted that there is direct support for that statement in the climatology of the Grassland. The prairie peninsula has had a climate more like that of the steppe than the eastern forests during most winters and the summers of major drought years. But during most summers its climate is more like that of the eastern forests than that of the steppe. Indeed, the climate of the prairies is "borderline," but the border is actually an extensive, wedge-shaped region. One might therefore expect to find the wild vegetation in the prairie peninsula different from that in the bordering regions of forest or steppe.

Thus each of the climatic regions of the Grassland has its unique wild vegetation which is well adapted to the recorded climate. The vegetation gradients appear to coincide with the climatic gradients. If the pattern of climatic gradients changes,

[42] A. L. McComb, and W. E. Loomis, "Subclimax Prairie," *Bulletin of the Torrey Botany Club,* LXXI, No. 1 (January, 1944), 46–76.

[43] E. N. Transeau, *op. cit.*, p. 436.

[44] F. W. Albertson, and J. E. Weaver, *op. cit.*, 411–415.

[45] A. L. McComb, and W. E. Loomis, *op. cit.*, p. 59.

[46] J. E. Weaver, and F. W. Albertson, "Effects of the Great Drought on the Prairies of Iowa, Nebraska, and Kansas," *Ecology,* XVII (1935), 567–639; also J. H. Robertson, "A Quantitative Study of True-Prairie Vegetation after Three Years of Extreme Drought," *Ecological Monographs,* IX, No. 4 (1939), 433–491.

[47] *Op. cit.*, p. 60.

the vegetation pattern may be expected to tend to shift also, as it tended to do in the 1930's. The transition from steppe through prairie to forest occurs in the shortest distance where there is the least fluctuation in the position of seasonal climatic gradients from year to year—on the northeast and southeast margins of the Grassland. And where the fluctuation is greatest—in the prairie peninsula—the transition from steppe eastward to forest is most gradual.

THE POST-GLACIAL, PRE-HISTORIC EXPANSION OF THE GRASSLAND

Several lines of evidence indicate a late post-glacial, pre-historic period with more frequent, widespread, and prolonged drought conditions than at present in the Grassland.[48] The dry period is believed to have been accompanied by the extension of the Grassland eastward through the lower Great Lakes region to the Mohawk valley (Fig. 21). This idea has been generally accepted.

The lines of evidence presented in the papers cited are varied. Bog pollen studies in the mid-West and northeastern United States show that northern coniferous forests occupied the area following the recession from it of the continental ice sheet. In the mid-West this stage in the bog record is followed by a relatively short period of oak dominance, indicating rising temperatures and less moisture, followed in turn by a long period of grass dominance, indicating drier conditions. In New England the change from the dominant boreal spruce forest of the late glacial stages to the present birch-beech-maple-hemlock association was interrupted by a period of oak-pine dominance, again indicating relatively drier conditions. "Degraded" grassland soils in parts of the tall grass prairies are now occupied by forests. This is taken as evidence that the forest has invaded an area that was once invaded by grass under drier conditions. At the time of white settlement, outliers of prairie extended eastward across southern Michigan and Ohio into Pennsylvania and New York. Also, the distribution of certain species of grassland reptiles at present extends eastward from the prairie region coincident with this postulated eastward projection of the Grassland. These facts support the idea that a post-glacial, prehistoric elongation of the Grassland had been largely overwhelmed by the invading forest when the white man arrived.

The sequence of events indicated by the various lines of evidence, in its broadest outline, appears to be this. Following the recession of the continental glacier, the central and northern United States were occupied by a sub-Arctic coniferous forest. As the margins of the glacier retreated farther toward the centers of glaciation, the boreal forest also retreated northward. Following the retreat of the boreal forest,

[48] This was pointed out by Transeau in his concise summary of the prairie peninsula problem in 1935 (*op. cit.*, p. 435). The foundations of the theory lay in large number of earlier studies cited by Transeau. Various studies since 1935 have repeatedly produced evidence for the same phenomenon; see, for example, A. L. McComb, and W. E. Loomis, *op. cit.;* R. W. Kraus, and G. N. Kent, "Analyses and Correlation of Four New Hampshire Bogs," *Ohio Journal of Science,* XLIV (1944), 11–17; Karl P. Schmidt, "Post-Glacial Steppes in North America," *Ecology* XIX (1938), 306–407; P. B. Sears, "Forest Sequence and Climatic Change in Northeastern North America Since Early Wisconsin Time," *Ecology,* XXIX (1948), 326–333.

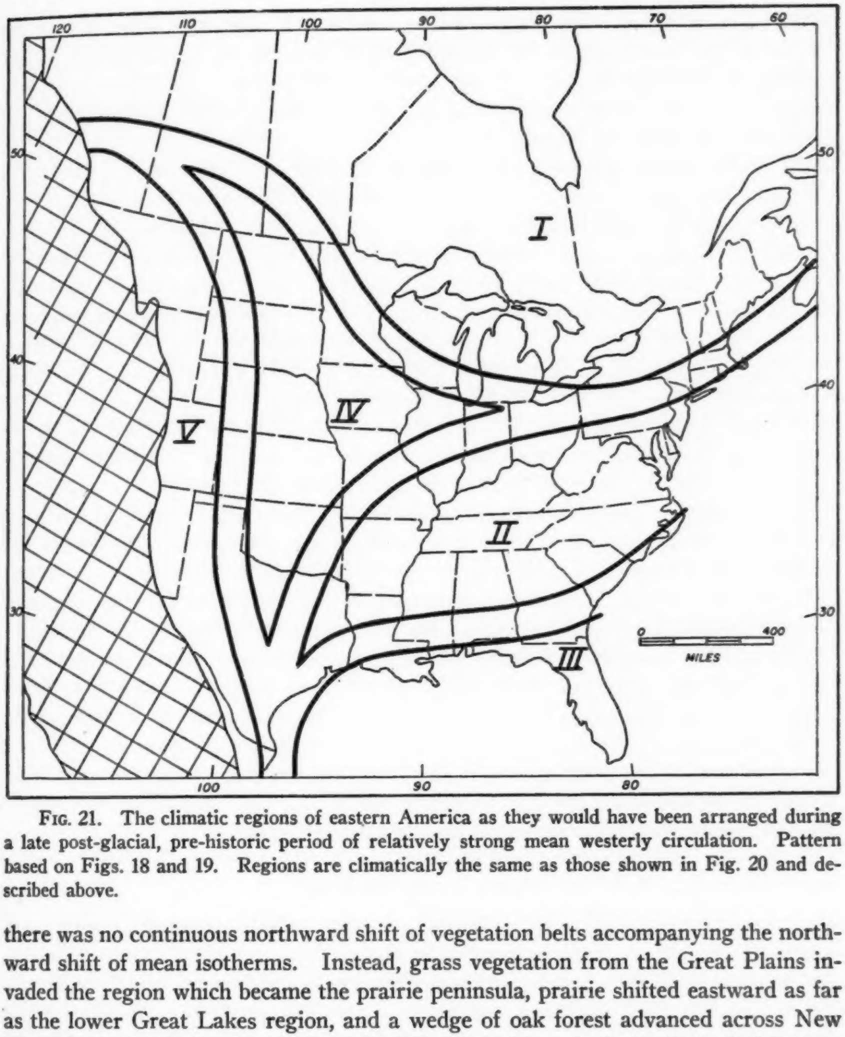

FIG. 21. The climatic regions of eastern America as they would have been arranged during a late post-glacial, pre-historic period of relatively strong mean westerly circulation. Pattern based on Figs. 18 and 19. Regions are climatically the same as those shown in Fig. 20 and described above.

there was no continuous northward shift of vegetation belts accompanying the northward shift of mean isotherms. Instead, grass vegetation from the Great Plains invaded the region which became the prairie peninsula, prairie shifted eastward as far as the lower Great Lakes region, and a wedge of oak forest advanced across New England from the west. Apparently following the end of the last glacial stage there was a period of relatively warm and dry summers affecting a wedge-shaped area extending eastward from the Great Plains (Fig. 21). From available data McComb and Loomis have concluded tentatively that this period in Iowa lasted from 3500 to 8000 years, was interrupted by a period of somewhat higher rainfall, and ended some seven or eight centuries ago.[49] At the end of that period the ad-

[49] *Op. cit.*, p. 61.

joining forests began to invade the wedge. It is now generally believed that the climate of this wedge caused the forests to perish or to be destroyed before the advancing Grassland. It is also widely held that the prairies which met the white settlers of the mid-West occupied the part of this wedge which had not yet been covered by the invading forest.

The pre-historic eastward expansion of the Grassland apparently occurred in the region of eastern America which has the greatest "airmass continentality" during periods of strong mean westerly circulation. It has been shown that a long-term increase in the strength of the mean westerly circulation from its present value would extend the climate of the Great Plains eastward and produce a climate drier than that at present in the region of the prairies. At the same time it would carry the present climate of the prairies eastward through the lower Great Lakes region (Figs. 18, 19). Changes in the strength of the mean westerly circulation are occurring continually. There are daily changes, seasonal changes, and changes from year to year and over longer periods. There is much evidence for the existence of a strong mean westerly circulation pattern during the periods of so-called "climatic optimum," from about 5000 to 1000 B.C. and again from about 400 to 1000 A.D. The evidence has recently been summarized by Willett.[50] Although the mechanics of such changes in the circulation of the atmosphere are not yet understood, Willett has suggested the likelihood of their relation to long-period fluctuations in solar output.

Thus the post-glacial eastward expansion of the Grassland may be explained climatically by a long-term increase in the mean westerly circulation in the middle latitudes. The more recent change to the climate observed during the period of instrumental record in the Grassland,[51] and the forest invasion of the eastern extension of the prairies, may likewise be explained by a long-period decrease in the westerlies to their present mean strength. These explanations make it possible to fit the problem of the geographical distribution of the prairies into a consistent hemispheric or world picture of present climatic regions and past climatic change fundamentally related to the general circulation of the atmosphere.

THE EFFECT OF FIRE

Pioneer settlers and many early scholars believed that the prairies were man-made—the result of frequent burning by the natives of central North America. Sauer has recently elaborated upon the fire hypothesis and has attributed the fires to "early man."[52] Fire may have been an important element helping to advance the prairie eastward during the post-glacial dry period and to retard the invasion of the prairies by forest from the end of the dry period to the time of white settlement. The relatively rapid advance of the forest in undisturbed places in the prairie region since

[50] H. C. Willett, "Long-Period Fluctuations in the General Circulation of the Atmosphere," *Journal of Meteorology,* VI, No. 1 (February 1949), 34–50, esp. 48–50.

[51] About 1000–1200 A.D. (cf. McComb and Loomis).

[52] Carl O. Sauer, "A Geographic Sketch of Early Man in America," *Geographical Review,* XXXIV, No. 4 (October 1944), 529–573, esp. 552.

white settlement suggests this. But fire, if not primitive man, himself, would simply have been one part of the ecological complex of a region with the climate of the Grassland. There is no reason for elevating it above other elements in the complex which were also influenced by the climate. Frequent and prolonged drought kills trees and "burns out" grass tops. Dry and dead vegetation burns easily. Thus the Grassland climates favor fire, just as they favor grass whether there are fires or not. Also, the precipitation pattern of eastern America during major drought years can explain why the influence of fire was restricted to the Grassland. The climate of the forests generally did not favor burning.

CONCLUSION

The geographical pattern of postulated post-glacial fluctuations of the Grassland fits the facts of the recorded climate. The pattern of the Grassland at the time of white settlement also fits those facts. The patterns, themselves, suggest very strongly that they were, in the words of an earlier author, "dictated by the master hand of climate."

SOME FEATURES OF EARLY WOODLAND AND PRAIRIE SETTLEMENT IN A CENTRAL IOWA COUNTY

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THE general relations of woodland and prairie settlement in Illinois are fairly well known, thanks to such studies as those of Barrows, Pooley, Poggi, and Brown,[1] but scant attention has been given to the historical geography of the Iowa prairies,[2] which, except in their western margins, did not present settlement conditions markedly different from those of Illinois.

Generally speaking, the major types of land in the Iowa Prairies at the time of white settlement were: 1) woodland, 2) well-drained prairie, and 3) poorly drained prairie and marsh. The well-drained prairie was the *most extensive* type except in a portion of the region of late Wisconsin glaciation, located in the north-central portion of the state, where poorly drained prairie was more common.[3] Woodland, commonly confined to stream valleys and sloping land adjacent to them, varied greatly in amount.

Figure 1 represents the distribution of woodland in Iowa. The most wooded sections were in the northeast and southeast; the northwestern quarter, roughly, was the only large portion of the state in which woods were scarce. The least well-wooded county in the eastern one-half of the state, Grundy, is known to pioneers and their children as a prairie county. In contrast, neighboring Hardin County is known as a wooded county. A glance at the map will show that the decription of Grundy was merited; that of Hardin was an exaggeration, but an understandable one when it is noted that Hardin County woodlots are reported to have furnished wood to pioneers even in the central part of Grundy. The amount of natural woodland reported for the counties of Iowa in the Iowa Census of 1875 is in general agreement with the distribution shown in Figure 1, although considerable cutting and clearing must have taken place in the older portions of the state. Grundy County was the

[1] Harlan H. Barrows, "Geography of the Middle Illinois Valley," *Illinois State Geological Survey Bulletin* 15, 1910, 64–125, especially 77–80; William Vipland Pooley, "The Settlement of Illinois from 1830 to 1850," *Bulletin of the University of Wisconsin* No. 220, History Series Vol. 1, No. 4, May 1908, 287–595; Edith Muriel Poggi, "The Prairie Province of Illinois," *Illinois Studies in the Social Sciences,* XIX, No. 3, University of Illinois, 1934, 124 pp.; Ralph H. Brown, *Historical Geography of the United States,* Harcourt Brace and Co., New York, 1948, pp. 206–211 and 236–254.

[2] The chief exception seems to be William Julius Berry, "The Influence of Natural Environment in North-Central Iowa," *Iowa Journal of History and Politics,* (1927), 277–298.

[3] This study is an outgrowth of an inquiry into the occupation and utilization of the poorly drained prairie lands of Iowa. A later paper, with Phillip E. Frandson, presenting results of the inquiry is being prepared. It constitutes a sequel to the present paper. Acknowledgment is due Frandson for careful checking of land titles necessary for accurate location of many of the pioneer farm sites mapped in Figure 2.

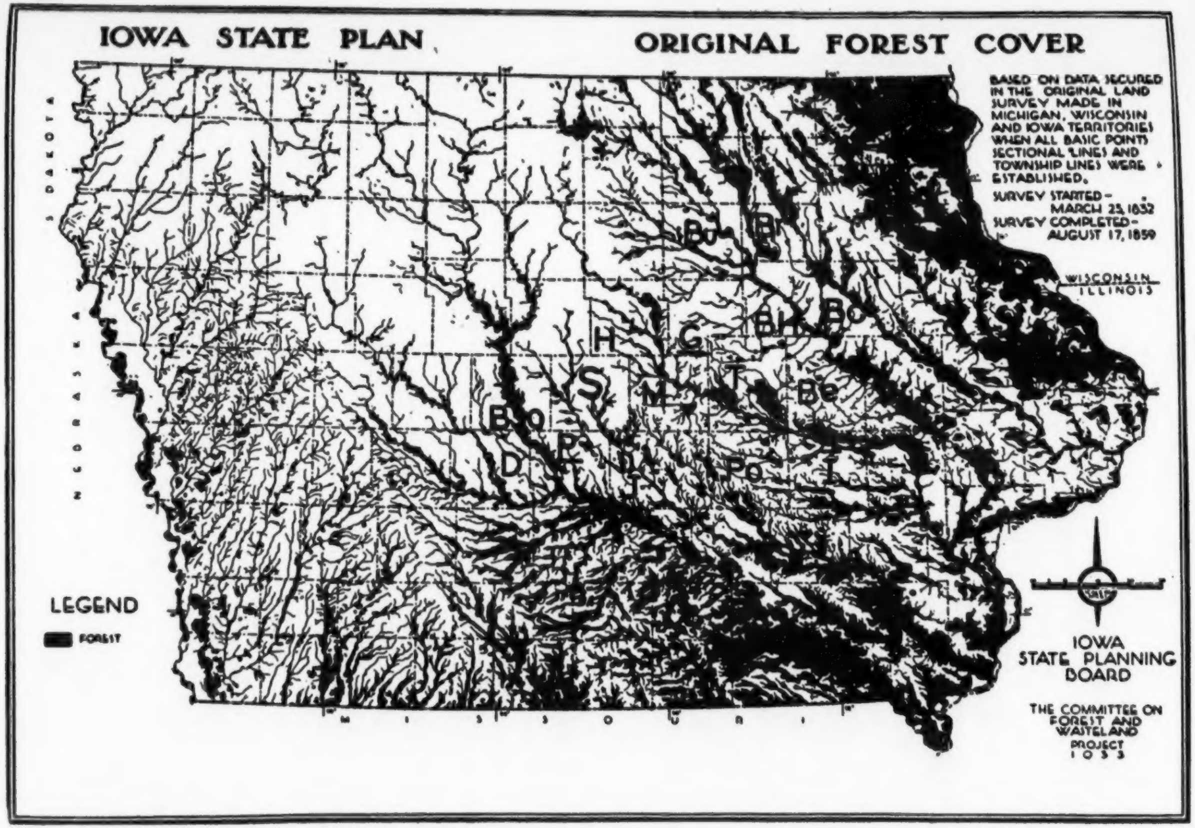

FIG. 1—Little prairie in Iowa other than in the northwestern quarter was distant from timber. Counties referred to in the text are identified on the map. Story, Grundy, Hardin, and Polk counties are marked by the letters *S, G, H,* and *P,* respectively. Other identifications are *Bu,* Butler; *Br,* Bremer; *B. H.,* Black Hawk; *Bc,* Buchanan; *Bo,* Boone; *M,* Marshall; *T,* Tama; *Be,* Benton; *D,* Dallas; *J,* Jasper; *Po,* Poweshiek; *I,* Iowa. The fourteen counties whose abbreviations are not underlined are those in which common conditions of settlement prevailed. Vegetation map by courtesy of Iowa Planning Board.

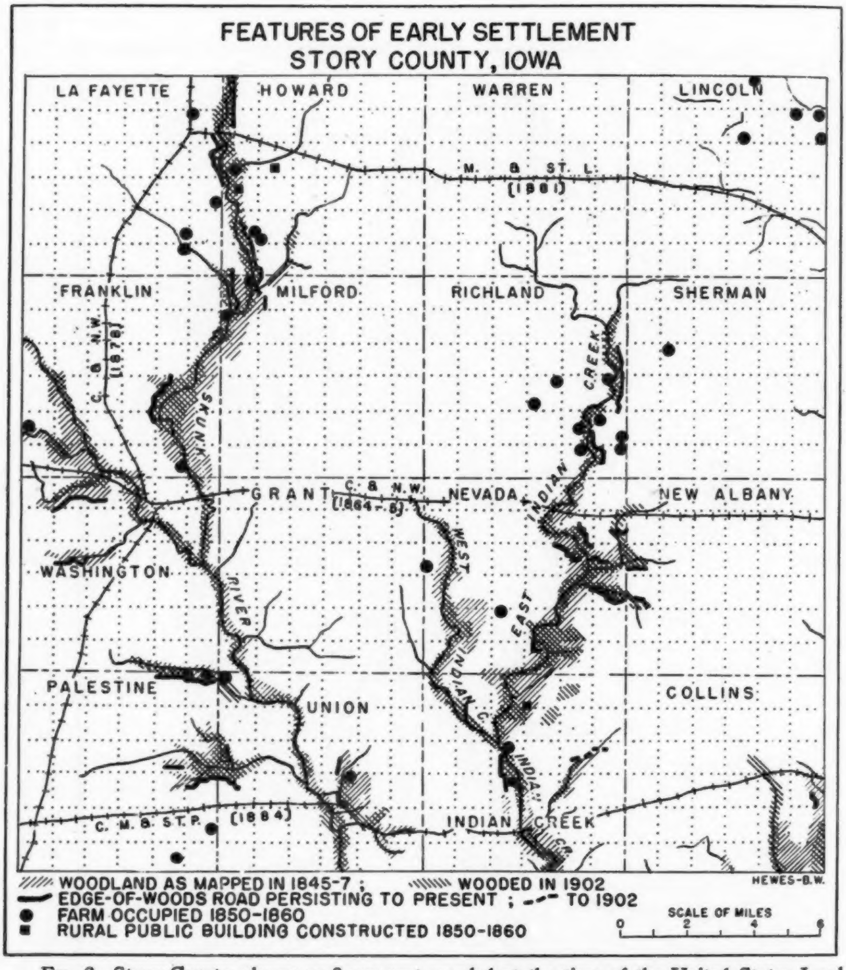

FIG. 2—Story County, shown as 8 per cent wooded at the time of the United States Land Survey, was about average for Iowa, and as in most of the state, the prairies were narrow. The distribution of woods, 1845–1847, is after township maps of the General Land Office. The woods in 1902, edge-of-the-woods roads, and farms of the first decade of settlement are based on the *Atlas of Story County*. Only in Lincoln, Richland, and probably, Warren townships, are the farms shown more than a small sample. The edge-of-the-woods location is general, but not without exception. The only railroads shown are those built before the entire county had become closely settled, i.e., about 1885.

only county in the eastern one-half of the state credited with less than 4,000 acres of natural woodland, whereas Hardin County and Story County, with which this

paper is most concerned, were much more representative of the east central and central portion of the state. The woodland acreages reported for the three counties in 1875 were: Grundy, 866; Hardin, 18,106; and Story, 14,165.

The occupation of the woodlands and prairies in Story County, a small part of that large portion of Iowa formerly characterized by narrow woodlands and narrow prairies, is the theme of this paper. Story County, like Hardin County, was representative of a much larger area in its settlement conditions.

In all, fourteen counties, including Story and forming the relatively continuous area shown in Figure 1, were similar in the following important conditions of settlement: 1) the combination of narrow prairies and still narrower woodlands, 2) smaller areas of sloughs or other wet prairie and marsh included within the well-drained prairies, 3) time of settlement, 4) place of origin of the early settlers, and 5) the chief crop of the pioneer period. Figure 1 shows the vegetational relations mentioned. The occurrence and relative extent of well-drained and wet prairie at the time of settlement can best be inferred from the soil maps of the United States Soil Survey. Story and the other counties shown had in 1860 for the first time in a decennial census year average densities of population of 6 to 18 per square mile, acquired entirely or in the main in the preceding decade. The density of 6 to 18, according to the U. S. Census of 1880, showed "the existence of defined farms or plantations and the systematic cultivation of the ground, but this is either an early stage of settlement or upon more or less rugged soil." Clearly, an early stage is represented for central Iowa. The population, as shown by the 1880 census, was predominantly from the Northern States and varied from about 5 to 25 per cent foreign-born. The chief crop in 1880, and in most counties from the earliest settlement, was corn.[4] Generally speaking, the counties having the settlement conditions listed above were set off from adjacent portions of the state in the following respects: on the north by a region in which wheat was the chief crop; on the east and southeast by earlier settlement; on the southwest by absence of sloughs; on the northwest by more wet than well-drained prairie, and, commonly, less timber and later settlement. The fourteen counties so distinguished form a continuous block of fairly regular shape except for nearly timberless Grundy County, where settlement was delayed, and Polk County, which is excluded on the basis of earlier settlement.

EARLY WOODLAND AND EDGE-OF-THE-WOODS SETTLEMENT

Figure 2 represents for Story County both the woodland distribution immediately preceding white settlement and that mapped after close settlement.[5] The woods as

[4] Another meaningful generalization, but not a distinguishing feature of the area under consideration, is that throughout the eastern one-half of Iowa nearly all counties acquired densities of population in excess of 6 per square mile in advance of railroad construction. Neither did another important regional characteristic, the extensiveness of level to rolling land, constitute an important settlement condition variable between the 14-county area and bordering country.

[5] *Atlas of Story County*, Iowa, the Huebinger Surveying and Publishing Co., Davenport, Iowa, 1902, shows woodlands about 1902.

reported by the United States surveyors in 1845–1847 were probably mapped quite accurately in view of the conspicuousness of woods in a prairie country, the use by the surveyors of trees as reference points in the locating of section corners wherever possible, the fact that all section lines were traversed by the surveyors, and that there was general agreement of the distribution of woods shown with the testimony of early settlers. Also, the acreages in natural timber reported by townships in the Iowa Census of 1875 although, for the county, smaller by one-half than that shown on the surveyor's maps, are generally proportional.

The woods found by the early settlers were confined almost entirely to valley bottoms, terraces, and sloping valley sides.[6] The originally wooded area of the county measured about 45 square miles, or approximately one-twelfth of the area of the county. The distribution of woods within and adjacent to the county was such that only a small area, roughly a township in extent, was as far as five miles from timber. Land farther than five miles from timber was found chiefly in the northern and western parts of Warren Township and adjacent portions of Howard and Lincoln. In 1902, the wooded area, not counting small isolated windbreaks and woodlots, totaled about 26 square miles, with some extensions as well as retreats to be noted.

The woods consisted of mixed hardwoods. As reported by an early settler, "When the writer settled in the township [Lafayette], 1856, there was a goodly amount of timber along the river [Skunk] consisting largely of white, burr, black, and red oak, black walnut, butternut or white walnut, hard and soft maple, bass-wood or linden, cottonwood, honey-locust, coffee-nut, hickory, elm, etc., etc."[7] The United States surveyors in the same township nine and ten years earlier, who described the locations of the few section corners located in the woods in respect to burr, black and white oaks, black and white walnut, elm, black ash, and hackberry trees, reported diameters ranging from 8 to 24 inches.[8]

A reminiscence about Union Township contains the following description and appraisal.

> It has several creeks running through parts of the township, besides Skunk river, which runs entirely through the township from the northwest to the southeast and at one time was heavily timbered on both sides with oak, elm, black walnut, and maple, but few oak and walnut remain to be seen at this time [1902]. The early settler fenced this land with rails split from the best oak and walnut to be found, and even at this day you may now and then see an old worm fence of black walnut rails split forty years or more ago.
>
> Ballard and Walnut creeks, both timbered streams, enter the Skunk from the west, and in small streams passing through Center Grove on the east, also heavily timbered with ash and kindred woods. [Some omission apparent.]

[6] In the latter type of site, the woods had spread, presumably recently, onto soils which, according to the Soil Survey, preserved strongly characteristics determined by their formation under prairie conditions. In other words, some prairie soils were occupied by woods. That the same succession had occurred elsewhere in the prairie region is a matter of common report.

[7] *Atlas of Story County,* Part I, p. 5.

[8] Field notes of United States Surveyors.

Union township has been one of the most, and probably is yet, the heaviest timbered township in the county; a condition the early settlers first looked for [for] shelter and firewood.[9]

Of the principal land types in the county there is little doubt that the woodland was the one most esteemed in the earlier years of settlement. The advantages of the woodlands were several and important, including ready sources for building material, fencing, and, particularly, firewood; a measure of protection against the biting winds of winter and against raging prairie fires; better drainage on the commonly sloping valley sides than was generally available; and, in part, soils which had not yet lost their qualities of prairie fertility.[10] Furthermore, the prairie areas immediately adjacent, which were readily available for grazing or cultivation, tended to share the superior drainage of the sloping wooded areas.

Nathan H. Parker, the author of several immigrant handbooks and a strong advocate of the advantages of the Iowa prairies, appreciated the dependence of prairie settlement upon local timber supplies. His estimate that one-tenth of the state was timbered was good, and his emphasis on geographical distribution was sound. In his words, "The unequal distribution of the wooded land is a greater objection than its actual quantity. Sometimes the prairies are from twenty to forty miles in width, thus making timber inconvenient. These, however, are rare cases. . . ."[11] He admitted, however (p. 71), "There is but one great deficiency in our state—the scarcity of timber." Incidentally, the Iowa Census of 1875 reported, after considerable clearing had taken place, somewhat more than six per cent of the land of the state as natural timberland. The newcomers could be thankful for the honest and largely informed appraisal of the timber resources of the state contained in Parker's handbooks.

Local testimony on the woodland or edge-of-the-woods location of earliest settlement appears conclusive. The following very specific statement is representative:

The first attempt at settlement in Howard township by white men was made by Jesse and Isaac Smith, later in the fall of 1852. They built a little cabin in the edge of the timber in the southeast quarter of the southwest quarter of section 18 [near Skunk River]; but the season was late, and with no provision for the winter, and becoming afraid of the Indians, they went to the south part of the state to spend the winter; returning in the spring of 1853 to find their cabin burned, probably by prairie fires. With them came their father, 'Old Uncle Jimmy Smith,' and family, and their brothers John and Sam. About this time also came Isaac Blade, the Primes, Griffith, Bracken, and perhaps a few others, who built their little cabins along the edge of the [Skunk River] timber, and began the life of veritable pioneers.

It was the early spring of 1854 that I came to Howard township. The country was wild and almost untouched by plow. However, a little [plowing] had been done the previous season, and this was planted to corn and tended by ox-power. . . . The prairie lay broad and fair, and the work of development was all to be done.[12]

[9] *Atlas of Story County,* Part I, p. 3. The distribution of woods stated is in harmony with that of the map based on the surveyors field notes (Fig. 2).

[10] Reference chiefly to sloping phases of the Clarion (prairie) soil which had been invaded by woods locally.

[11] Nathan H. Parker, *Iowa As It Is in 1856; A Gazeeter for the Citizen and a Hand-book for the Immigrants,* Keen and Lee, Chicago, 1856, p. 37. Estimate of wooded area on p. 36.

[12] *Atlas of Story Country,* Part I, p. 4. With the possible exception of a few individuals, white settlement in the county did not antedate the 1850's.

In view of the large number of names of early settlers appearing in the Reminiscences section of the Atlas of Story County, the exactness of the location of their land claims or farms given, and the inclusion of ownership plats (1902) in the atlas, it has seemed desirable to determine all the 1850–1860 farm locations which could be identified. This has been done on Figure 2.

Twenty of the farm sites indicated are based on direct testimony—i.e., statements that a certain pioneer lived on a farm which in 1902 was owned by a certain individual, or within a certain section or fraction of a section. Records of land ownership in an abstract office in the county were checked for the purpose of testing the accuracy of the testimony, both as regards the actual ownership of the land by the family named and the date of its acquisition. The remaining fifteen farm sites were located by comparing names of early pioneers with land ownership plats of 1902 and then eliminating all sites not actually acquired during the decade 1850–1860 by an individual having the family name of one of the listed pioneers. The memory of the old settlers was proved to be remarkably accurate whereas the inferential method proved less than 50 per cent reliable. Lands acquired from the U. S. government in 1860 were presumed to have been occupied before 1860 if so reported because of the likelihood of some delay in concluding transfers. The test of land-ownership without a record of residence would be of little validity since land speculation was common.

The results of the checking of pioneer sites were in general agreement with the edge-of-the-woods location claimed by the early pioneers. Such a type of location combined the advantages of access to wood and grass in generally well-drained sites. Even if many pioneers preferred woods the narrowness of the woodlands limited sharply the number of farms that could be made in the woods. Also, the large portion of the woods in valley bottoms, while valuable for timber and probably pasture, was generally too much subject to flooding to be used for cultivation. Of the 35 farms represented in Figure 2, only 8 were entirely or chiefly in the woods, 10 consisted of both woodland and prairie, and 17 were entirely on the prairie. Of the latter, 9, or more than one-half, were less than one mile from timber, 6 were from one to two miles distant, 2 were from two to three miles away, and none was more than three miles from timber. Actually, the settlement of the margin of the prairie was virtually contemporaneous with that of the woodland.

The United States census of 1860, in showing 20 per cent of the area of the county as in farms, indicates that a larger amount of prairie than of woodland was included in farms since the originally wooded lands covered only 8 per cent of the county. Assuming that considerably less woodland had been cleared by 1860 than by 1875, when about 23 square miles had been cleared (extent of woodland: 1845–1847, 45 square miles; 1875, 22 square miles), it appears probable that as much prairie as woods had been improved by 1860 for the total *improved* land in farms was reported as 37 square miles (24,711 acres). The acreage actually in crops may be estimated (as a result of computations involving production figures reported and yields reported at subsequent censuses) at little in excess of 15,000 acres, of which the chief individual crop acreages were approximately: corn 7,200; wild hay

4,400; spring wheat 2,600; oats 500; potatoes 250; and sorghum cane 150. It is impossible to assign even approximate amounts of crop land (except for hay) to the woodland and prairie portions, respectively.

The uneven density of pioneer farms by townships shown in Figure 2 is not in proportion to the actual number of farms then in the various townships. The map represents only a fraction of the farms. (The fraction is a significantly large one in view of the fact that, of the 471 farms reported in the county in the census of 1860, over one-fourteenth were mapped.) Some townships were not represented by a reporter in the Reminiscences section of the county atlas; some reporters were much more specific in giving names of early pioneers and in identifying farm sites than were others. The settlement of Lincoln and Richland townships is represented most completely on the map unless what is now Warren Township was not inhabited, which appears likely. None of the three was reported separately in the census of 1860, for each was at that time a portion of another township, suggesting meager populations. In the case of Lincoln Township, most farm sites may be shown on the map, for the reporter, who settled in the township in 1856, asserted that the seven, whom he called by name and whose farm sites he located by quarter-sections in five instances, were the only settlers in the township prior to the 1860's. No woodland was mapped for the township, although the two most easterly sites were essentially edge-of-the-woods in location in respect to a grove immediately east of the county line in Marshall County. The Richland Township reporters mentioned eleven early settlers by name. Eight farm sites were determined in the ways indicated above and are shown on the map.

The *topographical map* contained in the Story County atlas shows nearly thirty short stretches of road, mainly of winding course, which can be identified as edge-of-the-woods roads. In several parts of central Iowa, roads are so identified by long residents. Most of the edge-of-the-woods roads of the county, some 30 miles in total length, persist to the present (Fig. 2). Most of them, it can be assumed, are among the oldest roads in the county, running as they did through the earliest settled localities, as well as avoiding both woods on the one hand and the sloughs and ponds of the upland prairie on the other.

Whether access to wood or actual preference for woodland was the major concern, priority of settlement of woodland and adjacent prairie is apparent. The location of the early pioneer farms, which by 1860 occupied somewhat more prairie than woodland, although only prairie within three miles of woodland was occupied, suggest strongly major concern with the accessibility of wood, rather than fear that prairie soil was infertile. The same preference for wooded land or land adjacent to the woods was demonstrated in most parts of central Iowa—and at about the same time. For Polk County, to the south, it is reported by men aware of the importance of physical conditions in early settlement that, within two years after the earliest settlement (1844), "settlements were made in all the townships that had any forest growth."[13] The generalizations of Parker about the comparative availability

[13] E. H. Smies, George E. Corson, Charles J. Meister, "Soil Survey of Polk County, Iowa," *Advance Sheets Field Operations of the Bureau of Soils*, 1918, p. 10.

and price of woodland and prairie in central Iowa in 1856 probably were applicable to Story County at that time or very shortly thereafter.

There are yet large bodies of land subject to government price—$1.25 per acre. Early last season, there was much upon the line of the various projected railroads subject to sale; there are none at this time within less than ten miles of the railroad. The timber-lands of this section of country are all secured; nothing remains but prairie. The woodlands must be purchased at second rates, from $8 to $15 per acre.[14]

On the assumption that nearness to timber was a major consideration, and it is difficult to think of a more important variable in the settlement conditions of the county, the land included within the present sixteen townships of the county presented quite unequal attractions to early settlement. Considering both the amount and distribution of woodland, as shown on Figure 2, the most desirable townships to the early settlers must have been Nevada, Indian Creek, Union, Franklin, and Washington, in about that order. The more than average amounts of woodland in Collins and Milford were not sufficiently well distributed to make them equally attractive, we may assume.

Since the amount of natural timber reported for the sixteen townships in the Iowa census of 1875 seems to represent a roughly proportional reduction (one-half) of the originally mapped woodland of the county, it seems in order to let the timber acreages reported in 1875 represent the originally timbered areas in Table I. In the Table, the comparison is between the statistical units in use in the census of 1860, with woodland acreages further divided as reported in 1875.

The township populations reported in 1860 show a marked agreement with the accessibility of timber. Perhaps New Albany Township provides the only major discrepancy. The meagreness of the population of Collins and Milford townships is to be understood in part, at least, in terms of poor distribution of timber. Although subsequent censuses suggest that the majority of the population reported resident in the oversized township of Nevada in 1860 probably actually resided within the limits of the present Nevada, which had been reduced to its present size by 1875, there is no certainty that that is so. In case of Indian Creek Township there is less question of the localization of the population. For Indian Creek it is also possible to demonstrate what may have been true of the farm population of the present area of Nevada Township, that the decade of 1850–1860, the first decade of settlement, was the period of the most rapid growth ever experienced by the township. It is reasonable to assume that not only the woods but also the prairies of Indian Creek, nowhere distant from woods and in the main well drained, were already fairly well occupied, even though most of the farms of the county (and presumably of the township) contained less than 50 acres each. Indeed, the Iowa Census showed well over one-half of the total area of the township in farms as early as 1856.

[14] Parker, *op. cit.*, pp. 72–73. The first railroad entered Story County in 1864, but most of the land was in private hands before 1860. Private ownership outran settlement.

PRAIRIE SETTLEMENT

The upward reappraisal of the prairie distant from timber took place gradually. Increasingly, it became evident that the view reported by an early pioneer in what is now Howard Township that "It was not thought at that time [1850's] that the prairies distant from timber and streams would ever be settled"[15] was unduly pessimistic. Another, a resident of Franklin Township, reported a gradual movement onto the prairie thus, "After a time more settlers came in and began to settle on the prairie, as the first settlers all located in or near the timber. As emigration [sic] increased, they began to locate farther out on the prairie."[16] In 1857, according to another Howard Township pioneer, their neighbors "lived up the river toward Story

TABLE I

Township	Timber acreage in 1875	Population in 1860
Nevada		
Nevada	2308	
Richland	570	
Sherman	72	
Lincoln	30	
Warren	0	
E ½ Grant	slight	
E ½ Howard	slight	
	2980+	858
Indian Creek	2180	676
Washington		
Washington	1481	
W ½ Grant	399–	
	1880–	468
Franklin	1821	321
Collins	1210	136
Union	1157	407
Lafayette		
Lafayette	370	
W ½ Howard	664–	
	1034–	426
Milford	976	145
Palestine	794	295
New Albany	127	319
County Total	14,165	4,051

City [Northeastern Lafayette], a little ways out on the prairie. At that time the prairie land was not considered quite as good as the land along the streams, and partly because the only fuel we had was wood, it being before the discovery of coal in the county or along the Des Moines at Boone," which discovery and the introduction of barbed wire "were a great thing in making it possible to settle and improve the great prairies of Iowa."[17]

[15] *Atlas of Story County,* Part I, p. 4.

[16] *Ibid.,* p. 8. Probably the situation was similar to the "ringing" of the central Illinois prairies by concentric circles reported by Harlan H. Barrows, *op. cit.,* p. 80.

[17] W. O. Payne, *History of Story County,* S. J. Clark Publishing Co., Chicago, 1911, Vol. I, p. 164.

That there was a notable delay in the occupation of prairie distant from woods is shown in the early population statistics for the three townships which were entirely or almost without woodland. Figure 2 shows Warren, Lincoln, and Sherman as timber-less. The Iowa census of 1875 gave the natural timber acreages as 0, 30, and 72, respectively. The early Iowa or U. S. census population numbers for these townships, upon their being constituted organized townships with their present limits, were Lincoln 85 in 1867, 243 in 1870; Sherman 420 in 1870; Warren 132 in 1875, 463 in 1880. These were the last counties to be occupied at all completely. The combined populations of the three in 1870, assuming that a family or two lived in what is now Warren Township, was required to equal the population that Indian Creek had in 1860.

The advance onto the prairie was selective with the higher-lying, better-drained lands the objects of first choice. One of the early settlers in Nevada Township put it thus: "Many more came in the next few years [after 1856] and the converting of the wild prairies in [to] tillable farms began in earnest. Only the higher laying lands could be broken, and a system of tile drainage, such as for agricultural purposes had not been dreamed of."[18]

The intimate intermingling of areas of good drainage with those of poor drainage in most parts of the county, resulted, perforce, in the inclusion of some poorly drained land in many, if not most, prairie farms of the county. Generally, the only parts of the prairie that were free from locally poorly drained areas were narrow fringes above the chief streams, commonly no more than one or two miles wide on each side of the stream, and not in all cases that wide.[19]

A comparison of the location of pioneer farms, as shown on Figure 2, with the soil map of the county, showed 22 of the 35 sites to have been mainly or entirely on well-drained upland prairie soil (Clarion) and all but three included such soil. Poorly drained upland prairie soil (Webster) was mapped on 19 pioneer farm sites, although only one farm (located at the edge of a town, and, therefore, possibly a speculation) was mainly on Webster soil; mapped areas of peat occur in two of the farms. Terrace soils, some poorly, some excessively drained, were included in seven identified pioneer farms. Bottom land, commonly subject to seasonal flooding, made up part of 11.

Even the well-drained prairie, which was less "heavy" than the poorly drained portion, presented a problem in the "breaking." "For the sum of $2.50 per acre," according to Parker, "the prairie is broken up [by a paid sod-breaker], and often corn is planted the first year, by striking the axe into the turf and dropping the corn, which yields 15 to 25 bushels per acre. This is called sod-corn. The second year the turf is rotten, the ground easily tilled."[20] Elsewhere (page 76) he quotes a price of $2.25 and describes the breaking plow as 10 feet long, cutting a furrow 22 to 24 inches wide, and pulled by some five yoke of oxen. He reported shallow

[18] *Atlas of Story County,* Part I, p. 6.

[19] As mapped in H. R. Meldrum, D. E. Perfect and C. A. Mogen, "Story County, Iowa," *Soil Survey,* Series 1936, No. 9.

[20] *Op. cit.,* p. 69.

breaking conducive to early rotting of the sod. Later, with plows better adapted to the task, the farmer was in a better position to do his own breaking.

One of the early uses of the prairie doubtless involved less attention to drainage conditions than was true of crop-farming. This was the raising of cattle which, to a considerable degree, took place on the open range. Such was a report for timberless Warren Township, which was settled late:

> As the settlers became more numerous along the timber, they began to crowd out onto the prairie, and I moved into Warren Township in 1875 and found a few settlers had preceded me. . . . As the prairie was [otherwise] unoccupied, herding cattle was the principal industry. There were large herds brought here from Jasper County, Jones County, and from other counties south and east; there was range for all, and the cattle did well, and went home fat and sleek. . . . The township settled up fast, and in a few years we had no range for our stock; each man had to keep his stock on his own land. But land was cheap, selling at from $4.00 to $6.00 per acre.[21]

Statistical verification of the generally unfenced condition of the township is contained in the Iowa Census of 1875, which reported only 1,560 rods of fence, 690 rods of hedge, and 814 acres of cultivation in use by its 132 inhabitants.

Warren Township epitomized a shift in land use which must have taken place earlier in most of the rest of the county. The shift involved reduced emphasis on subsistence farming, more attention to surplus products. The 1860 census for the county showed nearly as many milk cows as beef animals and included tobacco, honey (probably wild), and maple syrup. Cattle represented a saleable product well adapted to pioneer occupance of the prairie. For the county, 1870, when most of the prairie was in an early stage of occupance, was the only federal census year in which more cattle than hogs were reported. With the passing of the open range and with improved transportation, increased emphasis was placed on feed grains and the feeding of farm animals, especially hogs. Corn was the chief crop from the start. Since 1880, oats, as well as corn and hay, have outranked wheat. Wild hay, which long ranked second to corn in acreage, was largely replaced by tame hay about 1900. Since the final passing of the open range in the 1880's, probably earlier in some parts of the county, a large although decreasing portion of the land has been in fenced pasture. By 1880, three-fourths of the land area of the county was included in farms; the major portion of the county was closely settled.

The dependence of prairie settlers upon the stream-side belts of timber for a supply of wood was long-continued despite the discovery of coal in the county, the planting of woodlots on prairie farms, and the coming of the railroad. Men still living in the county can recall that their fathers hauled wood from woodlots along the streams, and, in at least one case, considered buying such a woodlot after 1900. The ownership plats of 1902 contained in the county atlas show that small holdings were common along the originally wooded streams, but exceptional elsewhere other than for a few tracts adjacent to the towns. The United States census of 1870 had recognized a separate woodlot as a functioning part of a farm in these woods, "*A*

[21] *Atlas of Story County,* Part I, p. 3.

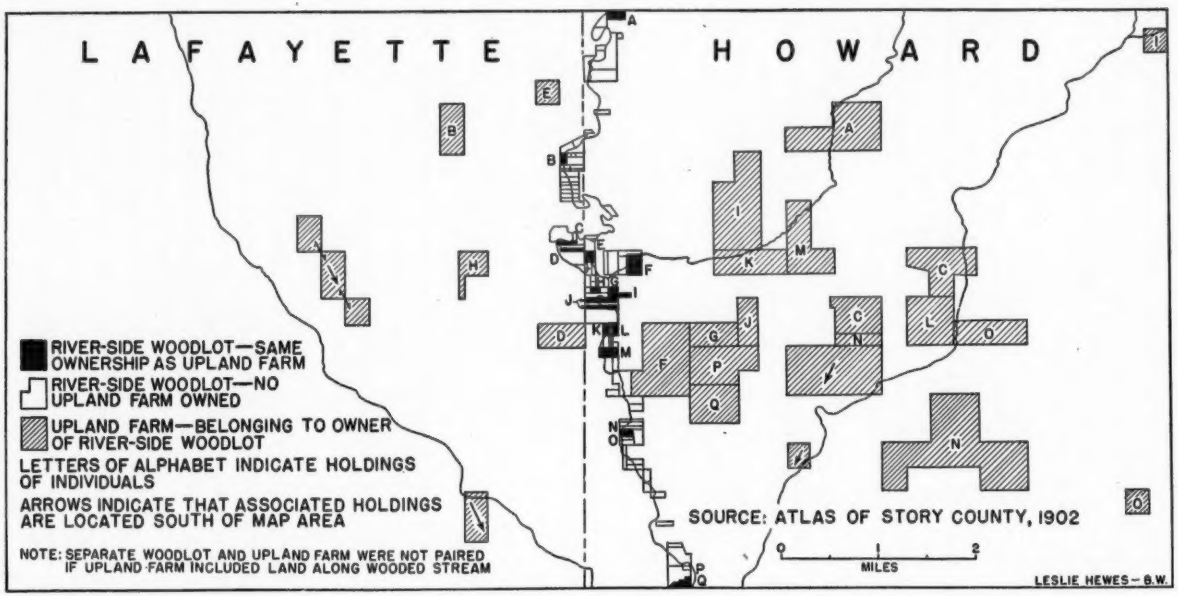

FIG. 3—Strong circumstantial evidence for the lasting importance of stream-side woodlots to life on the narrow prairies. The arrows indicate prairie farms owned by individuals who owned woodlots located in an adjacent township to the south. Since information as to ownership of woodlots north and west of the area was not available, it is probable that a number of prairie farms in the northern and southwestern portion of the area have been omitted, although actually paired with stream-side woodlots. Compare with figures 2 and 4.

distant wood-lot or sheep pasture, even if in another subdivision, *is to be treated as a part of the farm.*"[22] Thus, the assumption arises that separate woodlots and prairie tracts were then commonly paired in prairie region farms. This condition was probably then true of Story County, much of whose prairies had been occupied by 1870. Figure 3 represents, for two townships divided by Skunk River, the pairing of upland prairie farms with small wooded tracts along the stream. Common ownership of the physically unlike separate tracts is shown.

It can be seen at once that the upland farms were a limited distance from timber—in most cases no farther than four miles. A check in other portions of the county showed no greater distance between woodlot and prairie portion of farms. At an earlier date, pioneers report that, in timber-poor Grundy County, it was common practice to rent or own stream-side woods, partly outside the county, even for farms near the center of the county, presumably as far as 12 miles from the woodlots. The separate stream-side woodlot was in 1902 still a functioning part of many a Story County prairie farm located within a few hours driving distance of the woodlot. Many of the small stream-side tracts, presumed to have been woodlots, other than those owned by the owners of upland prairie, may have been leased for use of their wood on the prairie. Several examples of small stream-side tracts in 1902 no longer wooded must be considered relict forms, however. Figure 4 shows the distribution of small stream-side tracts throughout the county in 1902. Comparison with the distribution of woodland at the time of the original land survey and in 1902, as shown in Figure 2 is in order. Clearly, prairie settlement long remained dependent upon local timber. Today, however, the still largely wooded flood-plains are included in tracts which do not differ in size from those of the prairie upland.

To the discovery of coal and the introduction of barbed wire as aids in the occupation of the prairie, the coming of the railroad is added by most students. It lessened dependence on the woods[23] and favored the expansion of commercial agriculture. However, the continued existence of small stream-side woodlots past 1900 means that the coming of railroads to the county did not eliminate dependence on the woods nor offset entirely the advantage of living near the woods. Indeed, it would seem reasonable that the woodlot may have been visited as frequently as the railroad town by many farmers.

In the case of Story County, the coming of railroads did not exercise an all-important role in directing the location of agricultural settlement. Rather, in much of the county, close settlement was achieved while the nearest railroad remained as distant as five or even ten miles. In Indian Creek Township most rapid growth occurred between 1850 and 1860 and most of the land was in farms by 1856, when the nearest railroad was at Iowa City, roughly 100 miles away. In the main, the density of farm settlement was at no time in inverse relation to the distance to a rail line. For example, the townships traversed by the earliest railroad, the Chicago and Northwestern (Fig. 2), had in 1870, five or six years after construction of the

[22] Vol. 3, p. 71. Italics in the quotation above are supplied by the present author.

[23] As is emphasized for Illinois in Pooley, *op. cit.*, especially p. 312.

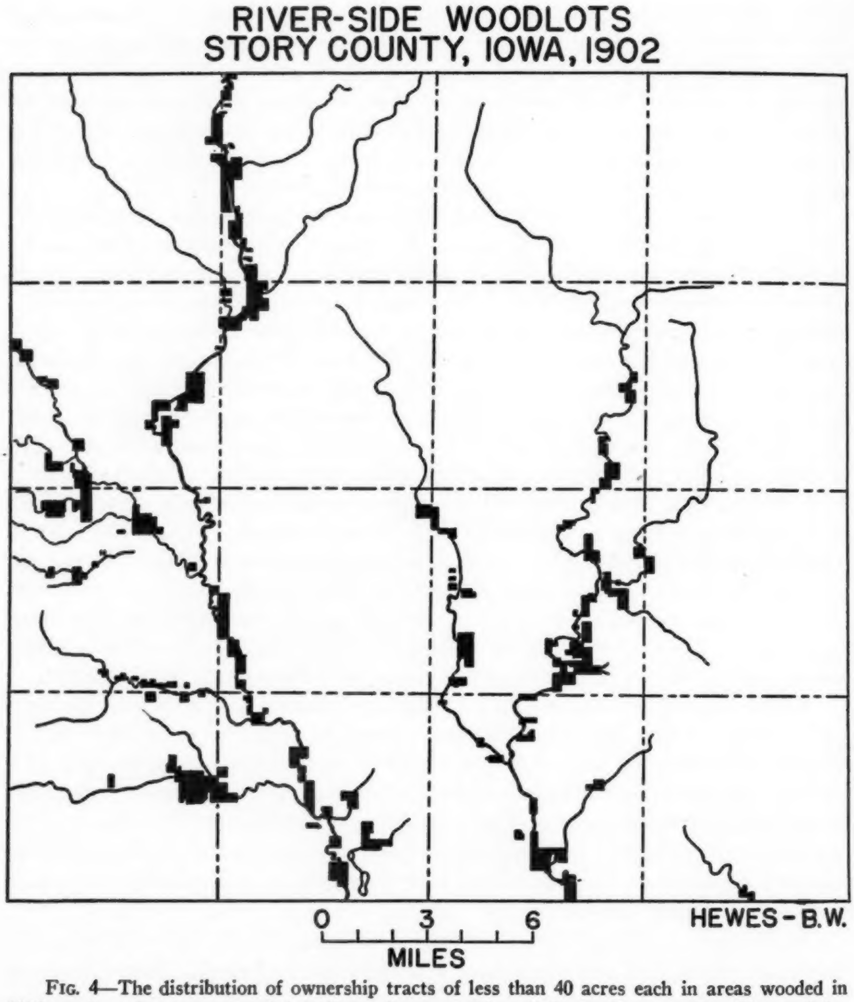

FIG. 4—The distribution of ownership tracts of less than 40 acres each in areas wooded in 1902, or in a few cases wooded earlier. Source: *Atlas of Story County*. See Figure 2 for distribution of woods.

railroad, a smaller farm population than the next tier of townships to the south, distant five to eleven miles from the nearest rail line, and so remained to 1880, the last federal census year before an east-west railroad crossed the southern tier.[24]

[24] 1870, Washington 1030, New Albany 777, Nevada 692, Grant 406, total 2842; Union 889, Indian Creek 826, Palestine 732, Collins 611, total 3058. 1880, 1160, 746, 816, 665, Total 3387; 888, 1212, 1302, 956, total 4358. All figures given exclude towns or villages reported separately.

In 1880, only three of the most southern townships and two northeastern townships remained distant from rail. Within a three year period, 1881–1884, both regions were crossed by rail. In two of the three southern townships a decline in farm population took place (probably due to increased size of farms in an area already closely settled); in the northeastern townships further increase occurred. In the first instance, close settlement had already been achieved; in the second, population had been small.

Perhaps a three-way classification of the townships of the county on the basis of the synchronization of the decade of most rapid population growth and the arrival or near approach of the railroad will help indicate the degree to which the railroad was an agency of settlement. One type is that in which the greatest growth of population, excluding incorporated places, took place in the decade in which the first railroad entered the township. Townships of this type were: New Albany, Grant, Washington in 1860–1870; Lafayette and Palestine, 1870–1880; Lincoln, 1880–1890. In another type, the decade of most rapid population growth took place at the time of the coming of a railroad to a bordering township. Townships of this type were: Sherman, Milford, Franklin, Collins, and Union, all in 1860–1870. Three townships experienced their most rapid growth at least a decade before a railroad entered the township or a bordering township: Indian Creek, 1850–1860; Howard, 1860–1870; Warren, 1870–1880. Two townships, Nevada and Richland, could not be classified because of the lack of definitive census data.

On the whole, one must conclude that the correspondence of the arrival or close approach of the railroad with rapidity of land occupation was good, but was somewhat less close than that which existed between the accessibility of timberland and the rapidity of land settlement.

CONCLUSION

In the settlement of Story County, timber constituted the first generally important locational factor. Accordingly, the woodlands along the valleys, the outlying groves, and the margins of the prairie were selected first. The accessibility of wood was probably a more important consideration than assumed greater fertility of the soil of wooded land. Nearness to woods continued to be a considerable advantage as late as 1900 when stream-side woodlots were still retained by many farmers on the prairies of Story County. First, the well-drained prairie and, later, the wet prairie were occupied, most of the former before the county was well-served by rail. In some districts of early settlement, increases in the size of farms and reduction of population took place immediately after railroads were built into them. If the details of Story County settlement, other than location and growth of towns, are representative of the *role* of the railroad, the role was not that of chief locating agent of and factor in settlement. Perhaps the prairies of Story County did not offer a sufficiently wide *stage*. Rather, there was a better correspondence between nearness to woodland and earliness of settlement.

In view of the large area of which the settlement conditions of Story County were representative, it may be assumed that the major features of early woodland and prairie settlement of Story County recounted here applied equally well to a large portion of central and east central Iowa, and perhaps in considerable measure to a still larger area in which woodlands penetrated the well-watered Mid-western prairies. It would seem in order to review the historical geography of the Iowa prairies with the purpose of trying to evaluate the relative importance of woodland and railroad, as well as of drainage condition, in prairie settlement.

POSTSCRIPT

Since the completion of the close settlement of the county in the 1880's, after little more than three decades of white settlement, the chief changes in rural occupance in Story County have been those involving intensification of land use. The drainage of wet lands and, lately, the use of hybrid corn and of commercial fertilizers have made intensification possible, but without altering the already established emphasis on feed grains, hay, and meat animals. Recently soybeans have been added as a cash crop.

In the process of the reappraisal of various types of land which took place under intensification, the wooded land, the earliest preferred site, and in large measure the sloping well-drained prairie lands which next attracted settlement, are no longer considered superior. The marked contrasts in the desirability of well-drained prairie and wet prairie no longer exist. To some degree, earlier judgments of relative worth have been reversed, particularly as between woodland and prairie. Perhaps, the persistence of a few miles of edge-of-the-woods roads, whose pattern is in contrast to the mathematical regularity of the other roads, is the chief direct landscape record of the early preference for a woodland or edge-of-the-woods location. Areally, the reappraisal is strikingly illustrated by the fact that most of the districts of important early settlement (listed on page 48) are today the least productive parts of the county. According to the Iowa Crop Production Index, Union Township had the lowest rating and Indian Creek and Nevada the next to the lowest ratings of the townships of the county; they were followed by Franklin and Washington. In contrast, late-settled Warren, originally without timber and with a large proportion of naturally wet land, ranked highest.[25] The figures for the early-

[25] "A Graphic Summary of Crop Yields and Land Productivity by Townships, 1940–1944," Iowa Department of Agriculture, Division of Agricultural Statistics, cooperating with U. S. Department of Agriculture, Bureau of Agricultural Economics, *Bulletin* 9.25, Des Moines, 1947, Fig. 10. The index figures are based on the total annual production in pounds of all grains and seeds, including corn, oats, soybeans, wheat, barley, rye, flaxseed, and popcorn, and clover, alfalfa, and timothy seed, divided by the number of acres in farms. The state average, 1,085 pounds, is given a rating of 100. Both low yields per acre and a small proportion of farm acreage in these crops would produce low index figures.

settled townships mentioned were Union 111, Indian Creek 118, Nevada 118, Franklin 120, Washington 122; and for Warren, the last township in the county to be closely settled, 157. The durable flat prairie land has come into its own.

THE ECONOMIC GEOGRAPHY OF A MICRONESIAN ATOLL*

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AS an incidental result of World War II the United States acquired a new island-strewn domain in the mid-Pacific. Sometimes popularly referred to as American Micronesia, the area coming under American control is now officially known as the United States Trust Territory of the Pacific Islands. Though the general facts are known regarding the trade of the islands there have been heretofore no detailed studies of their economic geography. The purpose of this paper is to present such a detailed study of one element of American Micronesia—Mokil, an island group in the eastern Carolines. The land area represented by all of the islands of the Trust Territory together is small and Mokil forms only a tiny fraction of this land area. But it is only through the detailed study of such unit areas here and there throughout American Micronesia that a reliable over-all picture can be obtained of America's new island charges in the Pacific.

In addition to its significance as a unit of the newly acquired island empire, Mokil is representative of a class of island clusters that is widely distributed throughout the tropical Pacific, the atoll. Since people behave differently even in similar natural environments, no atoll can be considered typical of all atolls in its economic geography. But atolls as a class *are* remarkably uniform in their physical characteristics and especially in the limitations they impose upon human occupance, and one cannot fail to be impressed by observable similarities even in the human phases of geography as one atoll after another is visited. The present study in addition to the information it contains regarding Mokil, an element of American Micronesia, is presented as a contribution to the economic geography of Pacific atolls as a class.

LOCATION AND PHYSICAL CHARACTERISTICS

Mokil is small even among atolls, a tiny cluster of islands in the vast Pacific Ocean. Its half a square mile of land may be compared with an average land area of about one square mile for the 80 or 90 atolls of American Micronesia. It is only when the easternmost Caroline Islands are represented on a map of large scale that Mokil is likely to appear (Fig. 1). Then it will be found to lie at 6° 40′ N. latitude and 159° 47′ E. longitude. It is 60 statute miles from its nearest neighbor,

* This study is one of several based on the author's seven weeks of field work in Mokil in July, August, and September, 1947. The project was one of a series of investigations throughout American Micronesia begun in the summer of that year. The general program was known as the Coordinated Investigation of Micronesian Anthropology (CIMA) and was sponsored by the Pacific Science Board of the National Research Council. Human geography was one of the fields represented.

Pingelap, another atoll, and 100 from Ponape, the nearest volcanic island.[1] Mokil is 3100 statute miles west-southwest from Honolulu by the most direct path, but about 5000 from Honolulu following the official pathway via Guam, Truk, and Ponape.

Like most other atolls of the South Pacific, Mokil consists of islands (*motus*), a lagoon, and a reef (Fig. 2). The largest island, Kalap, is a little over a mile in north-south length. Urak, though not so long, is almost equal to Kalap in area; Manton is about one-half as large as Urak. The lagoon, so characteristic a feature of most atolls, lies between Kalap and Manton. Elsewhere, surrounding the islands and fringing them on their seaward edges, is a shelf-like coral reef, and

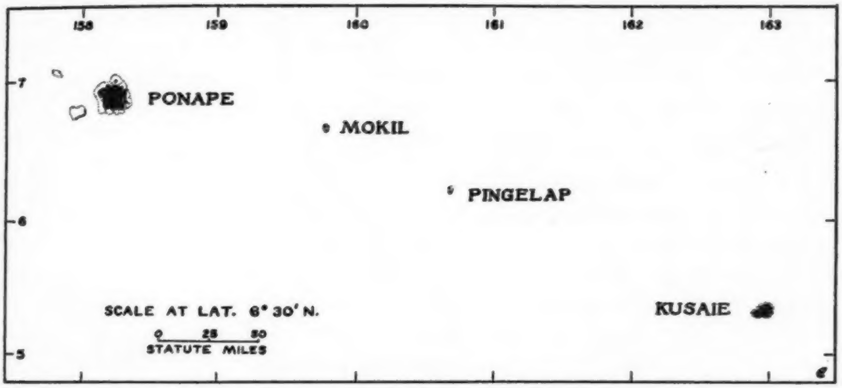

FIG. 1. Mokil in relation to neighboring island groups of the easternmost Carolines.

reefs underlie the water that separates Kalap and Manton from Urak. There is no ship channel through the reef, and the visitor to Mokil must end his journey by whaleboat or canoe.

In its landform characteristics Mokil is much like other atolls. The three islands are low and flat with the highest point less than 20 feet in elevation. Each island consists of a foundation of coral limestone covered with loose coral rock broken into sand and rubble and piled up by wind and waves at some time in the past.

There is little real soil in Mokil. The surface material is stony and drainage is excessive. With depth the stony veneer gives place to a finer textured material with enough organic matter to have a dark gray to black color, but the sum total is still far from good soil. The lack of a substantial soil sets one of the most severe limits to agriculture in Mokil as it does in atolls in general.

The climate of Mokil reflects the low altitude. Though there are no climatic

[1] Both in physical and in human geography the two atolls, Mokil and Pingelap, are in marked contrast to the neighboring volcanic islands, Ponape and Kusaie. See Raymond E. Murphy, "'High' and 'Low' Islands in the Eastern Carolines," *Geographical Review*, XXXIX (1949): 425–439.

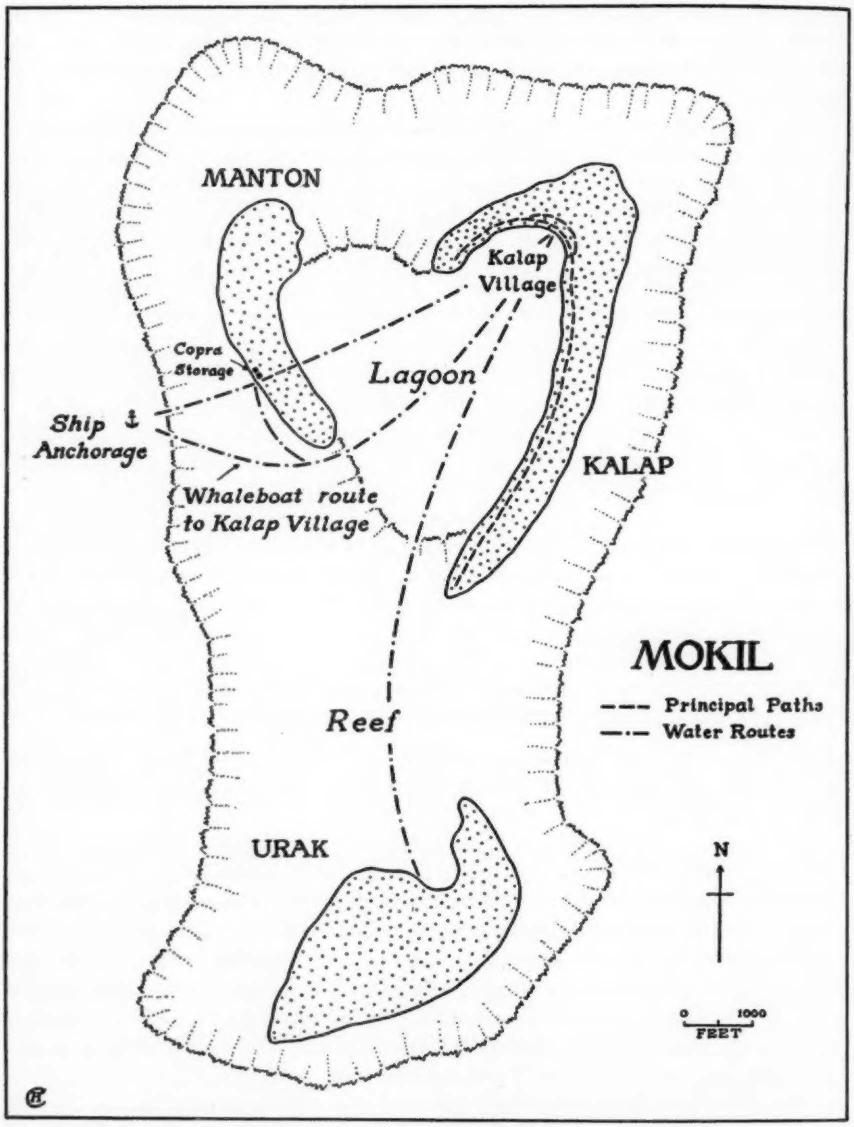

FIG. 2. Mokil consists of motus, a lagoon, and a reef.

records for Mokil itself, data are available for the neighboring volcanic island, Ponape, and certain differences between the two are a matter of common knowledge

in the region. Thus it is possible to arrive at an approximate picture of Mokil's climate. Temperatures are high throughout the year, probably averaging between 80 and 85 degrees Fahrenheit for every month. Similarly, it is estimated that the atoll's rainfall approximates 100 inches annually. Trades prevail most of the year. They are reported to be strongest in January and February, which is the period of least rain, and at that season they blow constantly from the northeast. In the July-August period, on the other hand, though trade winds still predominate they blow more often from an easterly or southeasterly quarter. Typhoons are rare, since Mokil lies well to the east of the main typhoon tracks. The last recorded one occurred in 1905.

In spite of the high rainfall total, extreme porosity of soils makes the problem of water supply serious. During the wetter portions of the year chief dependence is placed upon rainfall, which is collected in drums either from houses with galvanized iron roofs or at the bases of inclined coconut trees, their trunks scored to channel the water. Concrete cisterns with galvanized iron roofs were fairly common in the Japanese period; most of these are now cracked or otherwise useless because of poor repair. Open wells have been dug and are the chief reliance of the people in dry periods, but the water in the wells tends to be brackish and unpalatable.[2]

In view of the poor quality of atoll soils, the vegetation of Mokil shows surprising variety. The natives were able to give the writer the names, characteristics, and principal uses of 25 distinct trees. A few of these trees have been introduced by man, but certainly many, if not most, must be assumed to have arrived by the various natural means through which plant life spread over the Pacific. The coconut is by far the most common tree and pandanus ranks second in abundance. In addition to trees, several grasses and a number of other plants grow wild. Most of them are native to Mokil, and several play important roles in the atoll's economy.

The *motus* are poorly supplied with resources other than vegetation. Birds and coconut crabs add only slightly to the food supply, and Mokil has no mineral deposits of economic value.

The ocean, on the other hand, has resources of great value to the atoll people. First, of course, are fish. Especially are the reef and the ocean just outside the reef significant in this regard. And sea water itself is important, as most families even today evaporate it to fill part of their salt needs.

MOKIL'S PAST

Mokil has been known to the Western World for a century and a quarter and yet in its fundamental aspects life in the atoll appears to be much as it was before

[2] The problem of a supply of drinking water has to be faced by the field worker. The writer solved it by catching a bucket of rain water directly from a galvanized iron roof during heavy showers and then keeping this pail of water covered. The water soon became too warm to be pleasant tasting and sometimes after a few dry days there was little left, but at least it was not contaminated. In the field, "drinking coconuts" furnished the needed liquid.

"discovery" by Duperrey in 1824.[3] Apparently, people had been living in Mokil for a long time even then and *Cyrtosperma* (the great root crop of the atolls), coconuts, and breadfruit were basic crops even as they are today.

Yet is would be a mistake to assume that Mokil remained entirely unchanged by outside contacts. Trade soon resulted in new markets and new desires, and successive groups of outsiders left their impress on the atoll life. The missionaries, the Spaniards, the Germans, and the Japanese in turn modified the native culture. World War II and the coming of the Americans have brought still further changes. The 450 people who occupy Mokil today show in their features and in their culture the effects of these contacts with the oustide world.

AGRICULTURE

The economy of Mokil today is characterized chiefly by agriculture with fishing in an important, but secondary, role. Boatbuilding, an activity in which the atoll has gained considerable fame, is of significance chiefly as an adjunct to agriculture and fishing, and native handicrafts are a minor additional economic interest.

Mokil's agriculture is based on two very different classes of land (Fig. 3). By far the greater proportion may be classed as "coconut land"—normal atoll land with the low relief and the veneer of coral fragments typical of atolls. In contrast to the coconut land are the "wet gardens", which total less than 5 per cent of the atoll's area, but play a much more important role in agriculture than their size would suggest. These are man-made depressions in which organic material has been placed and has accumulated until a substantial black soil has resulted. In Figure 3 the wet gardens stand out in black; all the remainder of the land is coconut land even though locally breadfruit, bananas, or some other crop may be important.

The Wet Gardens

The wet gardens have certain uniform characteristics. All have been excavated by man.[4] All of the depressions are so low as compared with the average ground surface of the atoll that water stands in them for some time after rains. All, too, avoid the coast and the narrower sections of the islands because of danger of contamination by sea water. All have black soils for which man has been responsible. And, lastly, the wet gardens are cultivated in the fullest sense of the word (Fig. 4).

Actually, there are two kinds of wet gardens (Fig. 3). Most of the largest depression on Kalap and the smaller one just west of its southern extremity have been in existence a long time (Fig. 5). In these two ancient wet gardens land ownership is highly divided and is expressed in rows rather than in terms of area.[5] In con-

[3] For a summary of the coming of white men to the atoll see Anneliese Eilers' "Inseln um Ponape" (*Ergebnisse der Südsee-Expedition 1908–1910,* edited by G. Thilenius, *II. Ethnographie, B. Mikronesien,* Vol. VIII. Hamburg, 1934, pp. 359–404).

[4] The large depression in northern Kalap may be in part of natural origin, but if so the natural depression was further deepened by man long ago and has been extended from time to time along the edges.

[5] For details regarding land ownership in the wet gardens of Mokil see Raymond E. Murphy, "Landownership on a Micronesian Atoll," *Geographical Review,* XXXVIII (1948), 603 and 606.

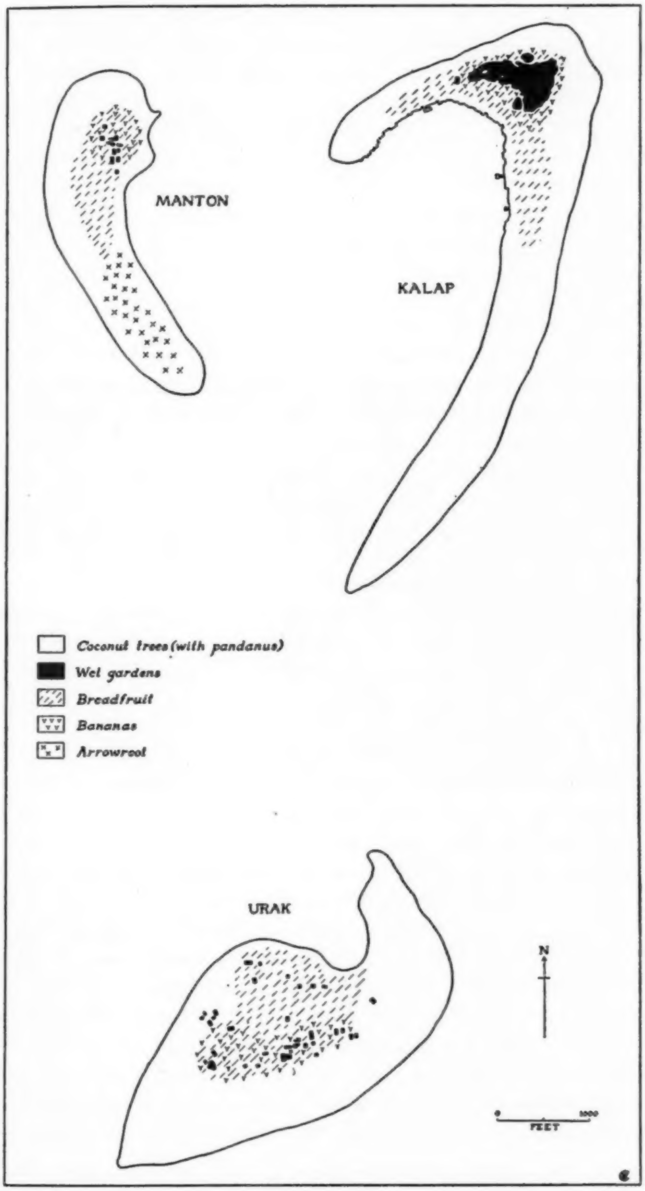

FIG. 3. Agricultural land use in Mokil.

trast to these ancient depressions are others that have been dug in modern times: extensions of the ancient wet gardens of Kalap, and a number of small pits scattered over the three islands.[6] Some of these modern extensions and separate pits are several decades old; a number date from World War II when Mokil was cut off from outside supplies for two or three years. A few have been dug since the War. The extensions and pits excavated in modern times differ from the ancient garden areas in the way in which the land is owned. Each of the modern excavations, whether it is a separate pit or an extension of the ancient taro areas, is likely to belong in its entirety to the family owning the surrounding coconut land.

Cyrtosperma Chamissonis, often mistakenly called "taro," is by far the most important crop of Mokil's wet gardens just as it is of comparable depressions in most other Pacific atolls. *Mwäng,*[7] which is the native name for the species, occupies perhaps 85 or 90 per cent of the land in the ancient wet gardens and nearly 100 per cent of the area in the modern pits and extensions. The reason for this contrast is that the soil in the ancient depressions has been accumulating over a longer period and is considered better for two other crops of the wet gardens, *Colocasia esculenta* (taro) and sugar cane, than is the soil of the modern excavations.

Mwäng is a large plant grown for its fleshy, barrel-shaped rootstock which may weigh as much as 50 pounds (Figs. 6 and 7). Since the mature plant stands 9 to 12 feet high and has leaves several feet in length, a wet garden with row after row of full-grown *mwäng* is an impressive sight.

Planting may be done at any time in the year. The section planted consists of the lower portion of the stalk cluster and the upper end of the rhizome. The *mwäng* plants are set in rows that are three to four feet apart, and within the row individual plants are placed about two feet apart.

Cultivation of *mwäng* consists of piling leaves and grass around the bases of the plants and, upon this, piling dirt dug from between the rows. The leaves of the *mes* tree (*Ceodes umbellifera*) are preferred just as are certain kinds of grasses, and bundles of leaves and grass are brought from the other islands to use in the big depression on Kalap. In cultivating *mwäng,* digging sticks or other implements may be used, but there is no good substitute for the hands since the aim is to work around the plants without disturbing the roots.

Generally a definite time schedule is followed in cultivating *mwäng.* The first application of leaves, grass, and mud is made three weeks to a month after planting; the second, six weeks later; the third, two or three months after this. Thereafter, the crop ordinarily receives no further attention except for weeding and the replacement of dirt in the rows when it is washed away.

Mwäng requires two or three years to mature. After that it may be left in the ground 10, 15, or even 20 years. It probably grows little if any after 15 years, but leaving it in the ground is a good way of storing the food until it is needed. Because

[6] The natives refer to these modern depressions as *bong,* in contrast to the two ancient depressions to which they apply the name *bwel.*

[7] *Mwäng* apparently corresponds to the *puraka* of the Polynesian atolls. See, for example, Peter H. Buck, *Vikings of the Sunrise,* New York (1938), p. 120.

of the large food yield of *mwäng* and its availability at all times the natives say it is the "boss" crop of the atoll. *Mwäng* is to the people of Mokil what rice is to many orientals.

Mwäng is prepared for eating in a number of different ways. It may be boiled or baked, or may be ground with pandanus, arrowroot, coconut meat, or molasses before cooking. In most meals in Mokil *mwäng* appears in some form and often in more than one form.

The second crop in importance in the wet gardens of Mokil is *Colocasia esculenta* or taro (Fig. 4). *Jaua,* the name by which the species is known to the natives, is like *mwäng* in that it is grown for its rootstock. Within the wet gardens it is confined almost entirely to the two ancient depressions of Kalap and even there occupies less than one-tenth as much land as *mwäng*.

FIG. 4. *Mwäng* and sugar cane rise above *jaua* plants in the ancient wet garden of northern Kalap.

Jaua differs from *mwäng* in a number of respects (Fig. 7). It is a much smaller plant with a rootstock weighing at a maximum only five pounds. Moreover, *jaua* matures in six months. Since the plants are smaller they are set closer together than *mwäng* plants, and since the growth period is shorter the intervals between successive periods of piling leaves and dirt around the plants are shorter. Finally, *jaua* is considered tastier than *mwäng*. It is a luxuy crop in contrast to the staple food crop.

A few stalks of sugar cane are interspersed with *mwäng* and *jaua* in the large ancient wet garden of Kalap. The cane is chewed for its juice, but is not otherwise used.

Coconut Land

Of the land above high tide in Mokil about 95 per cent falls in the category of coconut land, or *sab* to use the native term (Fig. 8). Coconut land is, in short, all

FIG. 5. The ancient wet garden area of Kalap, with Kalap Village in the foreground. Note the paths that cross the depression and the way in which the rows of *mwäng* and *jaua* extend from these paths at right angles. Along the edges of the ancient depression are recent additions, indistinguishable from the ancient area in the photograph. Typical coconut land surrounds the depression. Compare this picture with Figure 16. (Official U. S. Navy photograph.)

of the land of the atoll outside of the wet gardens. All of it is potentially coconut producing even though locally bananas or breadfruit may predominate and pandanus is everywhere abundant.

The coconut is by far the most important tree in Mokil. Even before the white man arrived the tree must have been a highly significant element of the atoll picture. It still finds many uses in the lives of the people, but the paramount use today

FIG. 6. A native of Mokil standing among his mature *mwäng* plants in the large wet garden of Kalap *motu*.

is for copra making. Through the sale of copra and little else the atoll dweller obtains the foods, clothing, and other merchandise from the outside world that he has come to consider so necessary. The fact that the natives themselves refer to everything except the wet gardens as coconut land shows the esteem in which the coconut is held.

Copra production is not evenly distributed in the three *motus*. Kalap produces more coconuts than either of the other two islands. However, all of the atoll's

people live on Kalap, and so great are the demands on that island's coconuts—for drinking, for human food, as feed for hogs and poultry—that Urak is a more important source of coconuts for copra. Manton, smaller than either of the other islands, is considerably less significant as a coconut producer and hence as a copra source.

The first step in actual copra production is harvesting the ripe nuts. In Mokil they are not taken directly from the trees, but are picked up, instead, from where they have fallen. Men, women, and children all help pick up coconuts from the several separate pieces of land held by the family.[8] This is commonly done once a month or at some intermediate time if there has been an unusually strong wind.

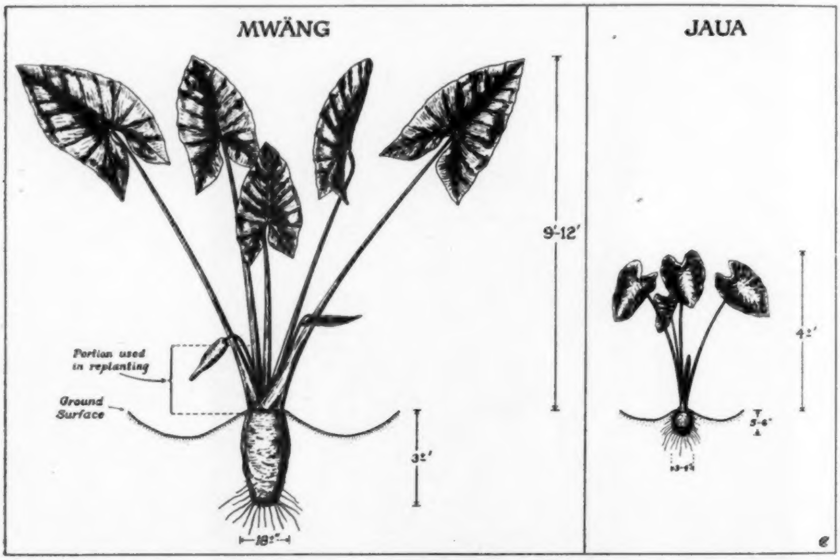

FIG. 7. *Mwäng* and *jaua* contrasted. (Drawn by Harold Champeau from the author's field sketches and photographs.)

The picking is rarely clean; some nuts are left, more or less accidentally, to sprout, whereupon they may be gathered for food (called *pär*) or left to form new trees, either where they have sprouted or at some site to which they are moved. The nuts for copra making are taken to some conveniently located point on the family's holdings, most often where a piece of land reaches the coast. Here they are husked to reduce the bulk.

The next step is the making of copra from the nuts. This is done at the homes of the people on Kalap, to which the nuts are taken from the other islands by canoe or whaleboat. Men and women work together at home, breaking the nuts and cutting

[8] For the manner of holding coconut land in Mokil see Murphy, "Landownership on a Micronesian Atoll," 606–607.

FIG. 8. Coconut trees in varying thicknesses of stands grow everywhere in Mokil except in the "wet gardens." In this picture taken in Kalap the men are making a canoe. To the left is the wide coral path edged with stones that runs from one end to the other of Kalap *motu*.

out the meat which is spread out to dry (Fig. 9). Four days of good sun are considered sufficient to dry the fresh coconut meat into copra. The copra is then ready for transfer to two storage sheds on the east coast of Manton, there to await arrival of the next station ship (Fig. 2). When a ship visits Mokil is generally anchors outside the reef west of Manton, and thus the copra is at the nearest possible point to the anchorage.

A few general facts regarding the copra business in Mokil may be added. Copra

FIG. 9. Coconut meat spread out to dry into copra in Kalap Village.

production goes on all year long, but reaches its peak in January and February at which time the wind is strongest and the weather driest. A good coconut tree on Mokil produces 40, 50, or even more coconuts per year. About 300 nuts are required to make one bag of copra weighing 100 pounds. It takes 20 bags of copra to make a ton, for which the natives received 80 dollars in the summer of 1947. Mokil's production is 70 or 80 tons per year, or about 300 to 400 pounds per acre of coconut land. The gross annual return to the people of Mokil for their copra is approximately $6000.

FIG. 10. Trunk of a pandanus tree showing "walking sticks" that branch off near the ground.

Most families would like to produce more copra, since it is the chief means of obtaining the merchandise to which they have become accustomed. An added urge results from the increasing population density which is steadily reducing the per capita copra production. But all available coconut land is already in use.

Though coconut trees are the common denominator of Mokil's coconut land, locally they are relegated to second place by pandanus, breadfruit, or bananas.

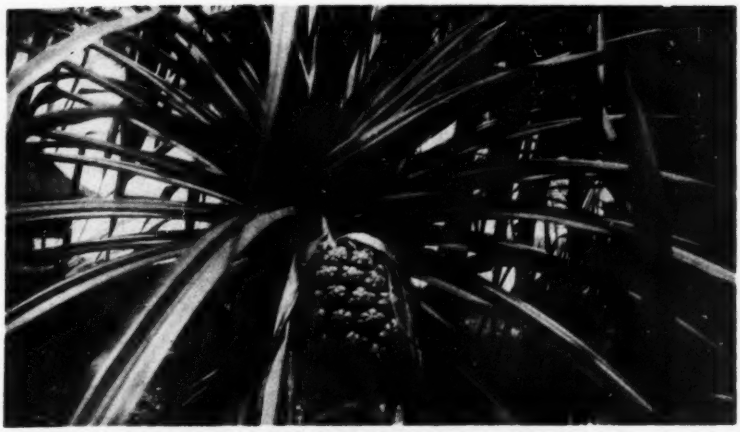

FIG. 11. Typical pandanus fruit.

Pandanus, like the coconut, is primarily an atoll tree, and there are 15 or more varieties in Mokil. Some varieties are planted or at least encouraged; others are part of the natural forest. In one variety or another the tree is fairly evenly distributed throughout the coconut land of the three islands though nowhere does it constitute any very large proportion of the forest. The visitor to an atoll soon comes to recognize the clusters of long, drooping, sword-shaped leaves that characterize pandanus, the "walking sticks" that support the lower trunk, and the fruit that in size and general appearance resembles a pineapple (Figs. 10 and 11).

The uses of pandanus, or at least of the better varieties, are numerous. In the first place, the leaves furnish Mokil's prime thatching material (Fig. 12). The fruit

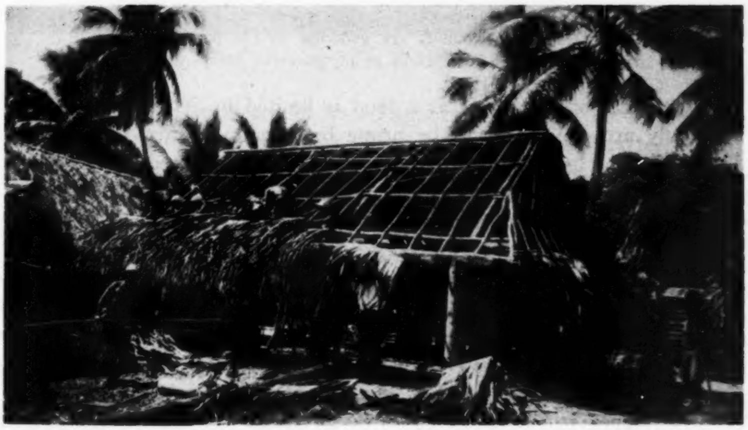

FIG. 12. Thatching a house with pandanus in Kalap Village.

of some varieties of pandanus is important as a food. The leaves are used in making mats, hats, and various other handicraft, and trunks of pandanus trees serve as crosspieces in all boat houses since they have the virtue of not sagging.

The breadfruit tree is another significant element in the atoll picture (Fig. 13). Though breadfruit is widely grown throughout the islands there are three areas of concentration (Fig. 3). Localizing factors are better-than-average soil and a forest dense enough to provide shade for the young trees. Urak ranks first among the three islands in number of breadfruit trees with Kalap a close second.

The fruit is harvested while still pea green in color. A long picking pole is used since the mature tree is 50 or 60 feet in height. The ripe breadfruit may be baked, fried in strips, boiled, or used in various combination dishes.

FIG. 13. A small breadfruit tree at the edge of the large ancient wet garden on Kalap. Around it bananas are growing in the partial shade.

The importance of breadfruit as a food is limited by its short season. Only June and July are considered to be prime breadfruit months. To prolong the period during which breadfruit can be used, some of it is mixed with coconut milk and stored in pits lined with leaves. The pits are covered with coral rock to prevent damage by rats and are protected against rain by special sheds with a roof, but without sides (Fig. 14). Pit breadfruit (*mär*) remains edible for years.

The breadfruit tree is considered to be the most important lumber source in the atoll. Its wood is used in making canoes, whaleboats, and paddles; and the logs are sawed by hand into lumber for house construction. Much more breadfruit lumber would be used if more trees were available for cutting, but unfortunately the supply is becoming increasingly scarce.

Breadfruit appears to have declined in importance in Mokil. It is not a commercial crop and thus has lost out to the coconut. As a food, breadfruit suffers rela-

tively since it is not as reliable as *mwäng*. It is available for only a few months of the year, and the yield varies considerably from year to year. With the atoll's ever-increasing pressure of population, breadfruit's relative decline is likely to continue.

Only a few other trees are planted. The papaya is the leading fruit tree as we commonly use the term, but it does not thrive as well as on the volcanic islands and is not very important as a source of food in Mokil. A few lemon trees on Urak and a few soursop trees (*Anona muricata*) complete the list of the edible-fruit trees of Mokil. Although some 17 or 18 additional trees are utilized for one purpose or another, only two are reported as ever being planted by the natives. It is of interest that one of these is the *mes* tree, the leaves of which are so much in demand as fertilizer in *mwäng* and *jaua* culture.

FIG. 14. Shed covering pit in which pit breadfruit is stored.

Several non-tree crops are of some importance in the coconut lands. The banana is outstanding in this group. The natives say that fourteen varieties of bananas are raised in Mokil, seven "cooking" and seven that are eaten raw. In spite of this imposing number of varieties, however, bananas do not thrive as well as they do in the neighboring "high" island groups, Ponape and Kusaie. Nevertheless, the fruit forms a valuable addition to the diet of the atoll. Boiled bananas are a common dish, and bananas are used in a number of food combinations. The natives report, moreover, that the banana is their premier medicinal plant.

Throughout Mokil, bananas are planted in sites where the soil is richer and moister than the average for the atoll (Fig. 3). A few invade the edges of the large wet garden on Kalap, and they are common on two islands of higher ground in this depression. They are important on the land that surrounds this wet garden, especially to the southwest and south where a belt of higher and somewhat richer

than average ground has resulted from past excavations. Bananas also attain importance as a crop in central Urak and to a lesser degree in northern Manton, in much the same areas as those in which the *mwäng* pits occur.

Arrowroot (*Tacca Leontopetaloides*), known as *mokamok* to the natives, is scattered through the forest on all three islands, but is especially abundant in southern Manton (Fig. 3.). Much appears to be growing wild, but some is planted. A starch made from the tubers is a food by itself and is used in various food mixtures.

Livestock, confined to the coconut lands, play only a minor role in the economy of Mokil. Since there is neither the space nor the feed for cattle, pigs and chickens are the only types represented. The pigs are kept in crude pens and are diminishing in numbers because the people prefer to use the chief swine feed, coconuts, for copra making. Chickens are fairly numerous, every family owning a few. They are kept almost entirely for their meat since eggs are not highly regarded as a food by the island peoples of the Pacific. Since the chickens wander and nest at will it is not surprising that both chickens and eggs are small.

THE FISHING INDUSTRY

The people of Mokil, like other atoll dwellers, place much dependence upon fish. Women take little part in fishing, but every man is a fisherman[9] and fish appear to compensate for the lack of livestock.

Often the importance of the lagoon to atoll people has been exaggerated. In Mokil, at least, the lagoon is of little significance as a source of food. Though the people depend much upon sea resources, they obtain nearly all of these on and outside the reef.

Fishing methods have changed with availability of equipment. Hooks and lines (either with bait or with artificial lures), nets, and spears are used depending upon the particular objective. There are still a few shell fishhooks to be seen, but they are used only when outside supplies are cut off. Similarly, the occasional use of fish lines made from the inner bark of an atoll tree reflects a shortage of store supplies. In the summer of 1947 the people listed steel fishhooks and all kinds of fish lines and wire leaders as being badly needed.

Bonito is the most prized fish. It is caught by line outside the reef with bait or with artificial lures. Although the bonito is caught all year it is considered useless to try for these fish except at dawn, and then only on those mornings when there is sufficient wind so that the sailing canoe moves briskly. Nearly as important as bonito, and caught in much the same manner, is *lajapule* or ocean bonito. Several other fish are important. Lobsters are obtained on the reef, and turtles are caught in the lagoon.

BOATBUILDING AND CARPENTRY

Boatbuilding is an essential part of the economy of Mokil. Whaleboats and canoes are needed for daily travel back and forth to the other islands; canoes, and to

[9] There is little specialization in Mokil. Thus every man is a farmer, a fisherman, and a boatbuilder.

a lesser extent whaleboats, make fishing possible; and whaleboats furnish the contact between the station ship and the islands. It might be thought that these needs would prevail on every island group in the Pacific and that they would all have boatbuilding industries. But the matter has gone much farther in Mokil, and the atoll is pre-eminent for its manufacture of whaleboats and sailing canoes.

In the summer of 1947 twenty-two sailing canoes and two whaleboats were under construction in Mokil. Breadfruit, coconut, and some 10 or 12 other kinds of wood are used in the industry, certain woods being considered especially suitable for specific portions of the boats. The making of a whaleboat, a task of much greater magnitude than canoe construction, is a group enterprise (Fig. 15). Approximately

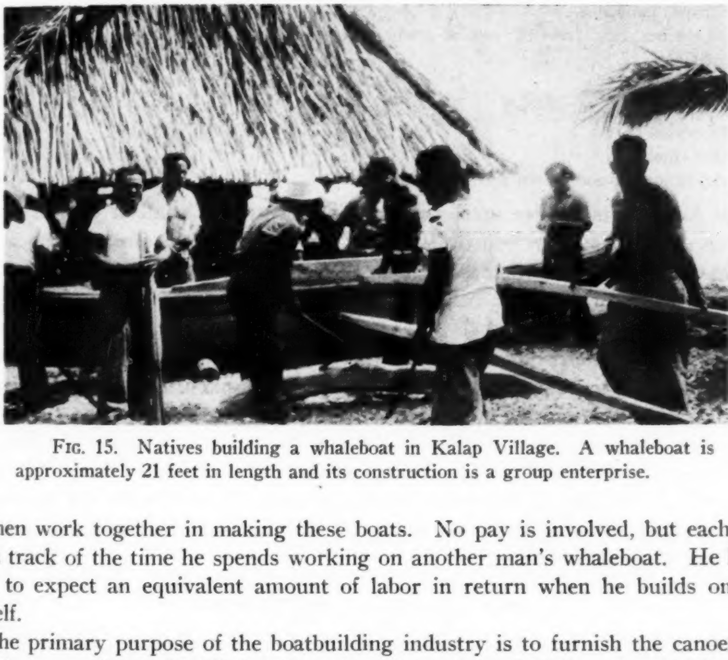

FIG. 15. Natives building a whaleboat in Kalap Village. A whaleboat is approximately 21 feet in length and its construction is a group enterprise.

ten men work together in making these boats. No pay is involved, but each man keeps track of the time he spends working on another man's whaleboat. He has a right to expect an equivalent amount of labor in return when he builds one for himself.

The primary purpose of the boatbuilding industry is to furnish the canoes and whaleboats needed in Mokil, but there is a demand for Mokil-made whaleboats in Ponape and at times the craft are sailed to this larger island group and there find a ready market. Unfortunately, the resources of Mokil set a limit on the industry since wood suitable for boat construction is becoming increasingly scarce.

Not only are Mokil men known for their boats; they are famed as exceptionally fine carpenters in general. In the summer of 1947 their services were in demand on Ponape where the main buildings of the Military Government base were being relocated. Their wages were an added source of income for Mokil, but one that could hardly be expected to be permanent.

NATIVE HANDICRAFTS

Native handicrafts have a place in Mokil's economy comparable to that of copra; they are a source of cash. But they are considerably less important in this respect than copra. The total value of handicraft products sold is probably considerably less than $1000 per year as contrasted with $5000 to $6000 for copra.

The chief handicraft products of Mokil may be briefly listed, together with the predominant raw materials used in each case:

mats: pandanus
fans: coconut, pandanus, turtle shell, and chicken feathers, the latter dyed with ordinary commercial dyes
belts: coconut and pandanus, some turtle shell for buckles
handbags: pandanus
hats: the best hats, coconut; second-grade hats, pandanus
rings (inlaid), shoe horns, watch bands, belt buckles, pocket combs: turtle shell
model canoes: wood (*sisen* and other atoll trees)

The handicrafts involve much careful labor. Practically all of the textile-type items on the list, and they constitute the bulk of the products, are made by women who do the work in their homes. All work in wood and shell, on the other hand, is done by men. Thus, they make not only the model canoes, but also the various turtle shell specialties.

The future of the handicrafts business does not appear bright. In the summer of 1947 handicraft products were being purchased at fixed rates by agents of the United States Commercial Company (a federal agency) each time the station ship came to the atoll and were distributed through the company's stores at Guam and other centers in the Pacific. The feeling seemed to be, however, that with further contraction in numbers of American service personnel in the Pacific the handicrafts would decline. Most of the items made are of little real value and would not be worth shipping far to market.

THE VILLAGE AND THE PEOPLE

Although the 450 people of Mokil get their living from all three islands they have their homes on Kalap, and on Kalap most families have their permanent living quarters in the area southwest of the ancient wet gardens. Reasons for this localization are not hard to find. As is so often true in atolls, the life of Mokil fronts on the lagoon. All three islands may be thought of as facing the lagoon, with its protected, easily-navigable water, and having their backs to the open sea. The most advantageous location on the lagoon front was naturally the place of easiest access to the great depression from which the people derived most of their food supply.

The cultural map of Kalap clearly brings out the importance of the village (Fig. 16). Here carefully built stone piers interspersed with short strips of beach

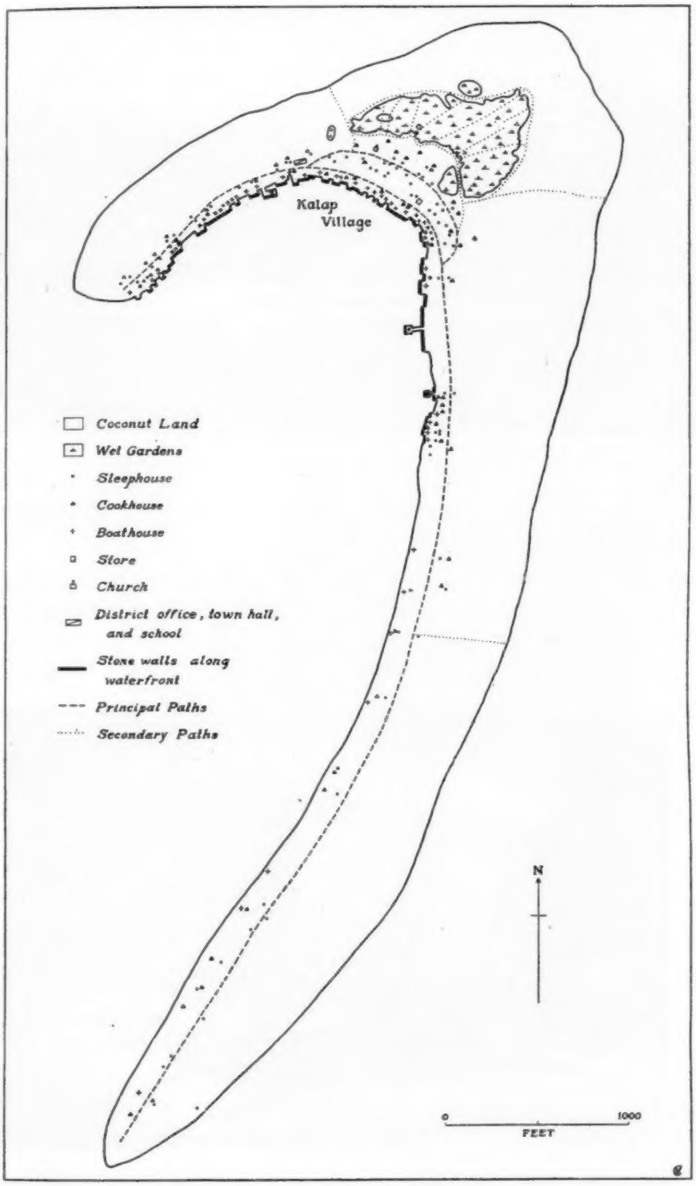

FIG. 16. Cultural map of Kalap *motu*.

FIG. 17. Rock piers alternate with beaches along the water front of Kalap Village. Although the original rock work was done in the German period the walls have been carefully maintained. Thatched boathouses and a typical cookhouse may be seen in the picture.

form the water front (Fig. 17), boathouses occur in almost unbroken succession, and sleephouses and cookhouses are crowded into a limited area (Figs. 18 and 19). The district office, the town hall, and the school form a single, continuous building. Farther to the southeast along the principal street or path is the store. About half

FIG. 18. Some sleephouses are built of wood with galvanized iron roofs. The interior of such a house reaches such high temperatures that the owners sleep under rather than in the house.

way between the store and the school is the landing place where the whaleboats come and go that make contact with the station ship when it anchors off Manton. On a secondary path a little northeast of the main street are more sleephouses and cookhouses, and on this secondary path, too, is the church, an important element of the cultural picture. The village, since it houses most of the people, is the chief center of copra making. Here, too, most of the boats are made and the handicraft activities carried on. In short, Kalap Village is the heart of Mokil life.

CIRCULATION PATTERN

Kalap Village is the focus of paths that reach to various parts of the island of Kalap, and boats come and go between Kalap Village and the other islands of the atoll and between the village and the fishing grounds. By way of whaleboat and

FIG. 19. Many sleephouses are little more than thatched shelters.

station ship, connection is made between Kalap Village and Ponape and, through Ponape, with the outside world. This circulation pattern is an essential part of the atoll's economic geography.

Running the length of Kalap is a long road (or wide path) that was built by the natives in German times (Fig. 8). It is the customary route of travel from house to house and to and from the store, the school, the district office, and the main landing pier. All of the sleephouses of Kalap are arranged along this path or along the secondary path, almost as well developed, that runs parallel to the main street through the heart of Kalap Village. The church is the primary attraction on this branch path.

Naturally, the main path is used least at either end. Its use increases toward the center of Kalap Village, and there the secondary street shares the traffic. The

movement is the result of many influences and varies with the time of day. It reaches considerable magnitude each morning about six o'clock when a shell is used as a horn to call people to church. There is a similar movement to and from the church for the several services on Sunday and for prayer meeting on Wednesday afternoon. There is much activity, too, when the "horn" is used to call people to town meeting; and when the children go and come from school. But it reaches its greatest magnitude when word is received that a ship has been sighted off Manton. Then everyone heads for the center of the village to greet the people who have come in on the ship, to hear the news, to sell handicraft products to the agent of the trading company, and to be on hand when the village store, newly laden with merchandise, opens for business.

FIG. 20. Family leaving Kalap by whaleboat for a day's work on Urak.

The main path and its auxiliary are used, also, for all sorts of traffic concerned with the daily life of the community—movement of recently dug *mwäng*, of pandanus for thatching a roof, of ripe coconuts for copra making, of drinking coconuts for home use, of wood for building a house or whaleboat, and of a wide variety of other items.

The secondary narrower path on which the church is situated is important for another reason. From it lead smaller connecting paths to still another path that completely encircles the large wet garden (Fig. 16). A number of minor paths, in turn, cut across the garden (Fig. 5). These are especially important since all families must have access to their rows of *mwäng* and *jaua* that extend at right angles from the paths. The significance of these paths across the ancient depression may be illustrated by the longest one of the group. Through following it, access is gained to 52 different, separately owned groups of rows of *mwäng* and *jaua*. Both men and women following the system of paths may be seen going to work, with bundles of leaves and grass for fertilizer; or they may be seen returning later, very

dirty after their efforts, and possibly carrying newly-dug *mwäng* or *jaua* or some sugar cane stalks.

Paths reaching from the main paths of Kalap to the outer shore of the island, though less clearly marked, are also important. On the reef off the outer shore the people gather minor items of fish food and shells, or they may use spears or nets to obtain fish. And all of these paths and other less distinct ones are used to bring in coconuts, breadfruit, pandanus fruit or leaves, *mes* leaves, and other products of the land to the various homes in the village.

Though Kalap is the principal island, Urak is almost as important and Manton is far from being negligible in the economy of Mokil. The connection with Urak is represented by the movement of whaleboats and canoes (Figs. 2 and 20). Generally, they go out in the morning taking a family to work. After disembarking, these people go by various minor trails, none of which is very well defined, to their Urak holdings. In the late afternoon the boats come back from Urak laden with coconuts, coconut husks, *mes* leaves, bundles of grass, pandanus, breadfruit, and other products. Generally, the boats returning to Kalap follow a standard course across the reef from the north shore of Urak and then across the lagoon, but, occasionally, where holdings are near the southern edge of Urak, boatloads of coconuts may be brought back at high tide from the south shore.

In similar fashion there is movement back and forth between Kalap and Manton, but to a lesser degree than between Kalap and Urak since Manton is smaller and fewer families have holdings there. This movement is easier since the normal course is across the lagoon without traversing any reef. But from Manton, too, loads of coconuts may occasionally be brought back to Kalap Village at high tide from the west or reef shore. Important in the Manton movement is the taking of bags of copra from Kalap Village to the storage sheds on the west shore of Manton, there to await the arrival of the station ship. Generally, the bags of copra are unloaded on the lagoon shore and carried by a well-defined path that leads to the copra storage sheds on the west coast, but occasionally the copra is taken directly to the copra sheds by boat at high tide.

Another important element of the circulation pattern is that between Kalap Village and the fishing grounds. Bonito fishermen go out during the night in order to be outside the reef at three or four o'clock in the morning; ordinarily they are back at Kalap Village by six or seven o'clock just as the village is stirring into life. For *redfish,* the fishermen go in the evening; and there are other similar movements synchronized with the type and habits of the various fish.

The station ship which arrives on an average of once a month represents still another element of Mokil's circulation pattern. The ship anchors west of the reef off Manton (Fig. 2). Then there is the movement of whaleboats to and from Kalap Village with people and merchandise. In going and coming from the lagoon these boats must use a poorly-defined channel across the reef south of Manton. Whaleboats are used, also, to take the copra from the storage sheds on the west coast of Manton to the ship.

The station ship that visits Mokil continues to Pingelap and Kusaie and then returns over the same route to Ponape (Fig. 1). But it is the arrival from Ponape and the departure for this large island group to the west that are of most significance to Mokil. There is, for example, a movement of people back and forth from Ponape. Some have land in Ponape to look after; others go to the large island group for temporary employment as carpenters at the government base. Young people from Mokil go to Ponape for training as teachers or as local policemen, or they may even be sent to the hospital at Guam from which they will return several years later as native nurses or doctors.[10]

Ponape is, moreover, the gateway through which economic goods come and go between Mokil and the outside world. The copra sent out by station ship reaches United States vegetable oil users; and handicraft products passing through Ponape are sold, largely to Navy personnel, and thus eventually reach many homes in the United States. In reverse, merchandise from the United States passes through Ponape for sale in the store in Mokil.

It is through Ponape, too, that the wishes of the United States Government reach the atoll. And the complaints or troubles of the people of Mokil are brought to the Ponape base and may eventually reach Washington.

MOKIL AND THE FUTURE

Mokil's greatest problem is overcrowding, a condition that is particularly serious in view of the rigid limitations of the atoll environment. In volcanic island groups, such as Ponape and Kusaie, there is always the possibility of new crops that will provide additional exports or will at least make a substantial contribution to the welfare of the people. In Mokil as in other atolls this possibility is practically nonexistent. No significant additions have been made to the agricultural picture for many years. And production of the one commercial crop, coconuts, has already been expanded to the utmost.

If the present rate of population growth continues then there are only two possible solutions. One is to dig more wet gardens. This would allow more people to live on a subsistence basis, but it would mean retrogression and would not be a popular solution. There has been no tendency in this direction. The second solution is emigration. Already a number of Mokil natives are living in Ponape and there is room for more. They may prefer the atoll environment, but in Ponape land is available and also opportunities for obtaining work at the government base.

There is another matter that must be of concern to any governed people, the matter of treatment by the governing nation. The oldest citizens of Mokil have

[10] During the writer's seven weeks in Mokil no doctor was available. There *was* a native medical practitioner left over from Japanese times, but he had been trained under the Japanese and knew no English and the labels on his bottles were in English. His abilities were not highly regarded even by the natives. Fortunately, however, health conditions in Mokil are excellent—much better than in the average island group of Micronesia. There is no malaria, but the field worker must look out for intestinal parasites and skin infections.

seen the Spaniards come and go, the Germans come and go, and then the Japanese. The American flag now flies over Kalap Village. What has this meant to the people and what will it mean? It is too early to tell. In the summer of 1947 the people were still profoundly impressed by the fact that they had become wards of what they considered the greatest of all nations. They are likely to judge their new rulers chiefly on an economic basis. Are they, the people of Mokil, more or less prosperous than they were under the Japanese? The answer is that there probably is little difference. The natives of Mokil as well as of other island groups of American Micronesia are paid more for their copra and handicraft products, but they pay more for the supplies they buy from the store.

Since the income of the atoll means little except in terms of what it will buy, the real test in the long run will be how well off the people are in things they consider essential. In the summer of 1947 the supplies brought to Mokil by the United States Commercial Company left much to be desired. Many items needed for everyday use were not arriving at all. This may have been partly due to the depleted economy of the United States, since even on the mainland many items of merchandise were still hard to get. Or, such lacks may be inherent in the distant location of the atoll. Supplies travel a long distance to get to Ponape and then must be reshipped to Mokil, Pingelap, and Kusaie. But if the natives are to be happy under United States rule then it is the supply of these "essential" items that must be looked to and not merely money paid to the natives. A well filled pocketbook may mean little in terms of fulfillment of daily needs in Mokil.

THE GEOGRAPHIC SIGNIFICANCE OF THE SOIL TYPE

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NOTE BY THE EDITOR. This paper was submitted for publication in the *Annals* by Wellington D. Jones and Kenneth C. McMurry, and is sponsored by them. The letter which accompanied the manuscript quoted, in part, a letter from J. O. Veatch to Wellington D. Jones giving permission for the use of the manuscript. Jones' letter concluded as follows: "I should warn readers not to 'get het up' at certain sentences in the last paragraph. Veach's [*sic*] general meaning is crystal clear to all except quibblers; . . . let's not get switched . . . from the field consideration of soil types to a wordy palaver on 'determinism'!"

The paper was written in 1936 at the suggestion of a group of geographers whose prime concern was training in field techniques. It was written for geographers; *not* for soil scientists. It has not appeared in print. It is here reproduced without alterations as a gesture of appreciation to the author, a true "field soils man," who has made much contribution to the training of many geographers.

SOIL in the abstract may demand no more or no less attention from the geographer than any other natural object or compound of matter. It is as simple or as complex, as little or as much is known about it, and, from a philosophic viewpoint, it is not different from any other designated grouping of matter about which we know nothing in an absolute sense, but about which we have accumulated relative knowledge and are able to make statements which we call "facts." However, it is assumed that geographers are not philosophic nihilists and are ready to believe that when soil is subdivided into its kinds on a scientific basis, a use for this knowledge will be found, especially if the kinds can be delineated on maps. The soil has an admitted human environmental significance; the soil map provides a means of evaluating soil as an environmental factor. Since the argument of this paper is that, after all, it is the kinds of soil, or the classification, that are of most value to the geographer, a brief mention of the development of the classification in the United States is here given.

The kinds of soil, or land previous to any scientific classification, were based upon use, or upon the crops and types of agriculture to which they were adapted, as determined by experience. Also, soils were designated simply as "good" or "poor" on the basis of productivity, and there were simple textural and structural kinds which bore a relation to ease or difficulty of tillage and management. There were also different kinds according to topographic situation, but usually "soil" and "land" in this case were interchangeable. Broad classifications of soil and land were made upon the basis of climate, as arid and humid, or upon other environmental factors, such as divisions, of local significance, based upon the original cover of vegetation. After separate sciences had been established, such as chemistry, physics, and geology, the professors of these were either called upon, or proffered their services, to aid the agriculturist. The geologist offered what appeared to be the most logical plan for a classification of soils. This plan was based upon the assumption that soil is

simply weathered rock and that a determination of the kind of rock would be equivalent to a determination of the kind of soil, and that a geological map, per se, would constitute a soil map. Further, soils underlaid by unconsolidated deposits might be classified on the basis of origin or manner of accumulation of those deposits. The chemist and the agronomist studied soil on the basis of analysis, the amounts of supposed plant nutrients, and almost entirely in terms of productivity for cultivated plants. The physicist supplied the mechanical analysis and applied laws of physics, particularly in the study of retention and movement of water; but, like the chemist, was primarily interested in the agronomic application of his research. The economist defined land in terms of productivity and money value. The scientific studies of soil here briefly mentioned and the kinds designated by travellers and early settlers had a value, and still have a value, but did not provide a scientific system of classification.

Beginning about 1914, a new concept of soil and new principles of soil classification were presented to this country, chiefly through the labors of the late Dr. C. F. Marbut. Dr. Marbut, through his translation of Glinka and by his independent studies of foreign literature, made great groups of soils, zonal in nature, familiar to us and caused us to recognize more clearly the biologic nature of soil, the differences in a soil according to stages in its development and the importance of the soil profile. Dr. Marbut adapted Russian investigations and ideas to the conditions in the United States, expounded his own principle that soils should be classified upon the basis of their intrinsic characteristics, not upon environmental factors, and worked out a broad scheme for the scientific classification of soils on this basis.[1] He pointed out the significance of soil and the new genetic concept of soils to American geographers in lectures, writings, and by conversation in a manner that no other individual could because of his profound knowledge of the subject and because throughout his life, after his college days at Harvard, he remained essentially a geographer. Due largely to the inspiration of Marbut, a very considerable body of literature on soils, of interest to geographers, has accumulated in this country during the past few years. A summary of the literature, especially foreign literature, a concise presentation of the new concept of soils and an authoritative description and pedologic discussion of the major soil groups has become available very recently in a book by Dr. J. S. Joffe[2] which also should be of interest to agricultural geographers.

The broad pedologic divisions, as established and mapped in the United States by Dr. Marbut in the Atlas, Soils of the United States, published by the U. S. Department of Agriculture, constitute a new kind of natural region which geographers should find useful. However, for the less academic studies, the local and more immediately useful, which have an economic or sociological implication, as in land planning, for example, smaller units of soil are necessary. The smallest unit in the

[1] C. F. Marbut, *Soils of the United States, Atlas of American Agriculture,* U. S. Department of Agriculture, 1935. The basic ideas of the classification were also presented in several previous publications.

[2] J. S. Joffe, *Pedology.* (New Brunswick: Rutgers University Press, 1936).

scheme of classification is commonly called a "type," although this word is loosely used and indiscriminately employed for the major groups, such as Chernozems and Podsols, or for other technical and non-technical divisions of soil, or land. It is with the small unit of the classification that this paper is chiefly concerned, and further with the unit of mapping of the soil surveys of the U. S. Bureau of Chemistry and Soils, since the maps cover about half of the area of the United States, and are, therefore, of greatest potential value to the geographer. The discussion of the geographic significance of the soil type practically resolves itself into a critical appraisal of these soil maps, since no other organization has developed a systematic scheme and applied it to any large percentage of the United States.

The Soil Survey was initiated by Dr. Milton Whitney in 1899. The surveys began with an attempt to map small units before the larger units were delineated and before any complete basis for a scientific classification had been worked out. The earlist maps are pioneer in character and the soil units, or types, are not, therefore, susceptible to exactly the same interpretation as the latest ones, which reflect the influence of the new concept of soil. The "types" in the earlier surveys are more likely to conform closely to local physiographic, or topographic, features, and to conform in areal distribution to the distribution of particular geologic formations. They are, therefore, more likely to constitute a broader natural land type to include a wider range in soil and greater diversity of microtopographic features than types which have been based upon the features of the profile and upon refined differences in the chemical and physical nature of the separate horizons of the profile.

It is highly important for the geographer to know that the "soil type" rarely represents a uniform soil condition throughout the area represented on a map by a certain color or pattern. Slight variations, which may be described as phases, and even small bodies of soils that are in strong contrast to the one which is supposed to be typical and dominant may be included. It is also important to know that boundaries between types cannot be drawn with mathematical accuracy but are, on the contrary, to a greater or less degree arbitrary. These things are to be expected, since no terrain is absolutely uniform but, on the contrary, exhibits variations in surface aspect, in its elevations, slopes, and depressions, and also since parent materials may vary lithologically both horizontally and vertically, and since in nature there is frequently a gradual change horizontally from one drainage or moisture condition to another. It follows that gradational or transitional zones are more common than the sharp definite line of separation. Because of the nature of the criteria employed and because so few practical laboratory and field methods for precise comparative measurement of the chemical and physical features are available for his use, the pedologist's comparisons of soil and land types are mainly qualitative and never precisely quantitative.

There are inherent weaknesses and deficiences in the scheme of mapping, apparent inconsistencies, and some confusion resulting from errors of correlation, the splitting of old "series" into several "new series" and "types" and changes in original definitions; but notwithstanding these things, the Soil Survey maps properly in-

terpreted constitute a great mine for the geographer. The ore does not assay the same from all parts of the mine, but the values in general are high enough to justify the workings.

The soil type of the detailed soil map is of value to the geographer: (1) as a basis for evaluating land resources or in making a land inventory; (2) as a means of explaining a land-use pattern, and predicting changes in any particular pattern; (3) in the field of rural land planning and rural zoning; and (4) in the delineation of natural land types or natural geographic divisions.

The fourth use is, I believe, after all, the most important one. It is possible for the geographer to construct his own natural land divisions or regions and not have to pay rent to the geologist, the physiographer, the climatologist, or even to the pedologist. The pedologist can make a contribution to the building. The kind of natural geographic division which I have in mind represents an intergration, a synthesis, of the physiographic and topographic elements, the soil element, and the natural vegetation, while at the same time, such a natural division can be made nearly a climatic unit. This may appear to be a large order, but I believe that it is possible to set up criteria for differentiating these land units and for mapping and correlating them.

Consciously, and unconsciously, several individuals have already made considerable contributions toward constructing such divisions, but I do not believe that any general scheme of classification has been proposed, and no map of the natural land divisions of the United States has yet been published which follows consistently throughout the same basis of differentiation for the separate divisions. The writer[3] has presented some ideas on the construction and method of differentiation of these so-called "natural land types" previous to this paper, and has made a practical use of such land types in the evaluation of orchard land in a county in Michigan.

Another idea is injected here, namely, the possibility of placing the comparison of any natural land divisions upon a quantitative basis. The desirability of accomplishing this should be generally admitted by geographers, especially for the comparison of very similar land types. Where proper factual data are available this can be done by comparing measured amounts respectively of: (1) level upland; (2) slopes, arranged in classes according to gradient; and (3) low land. Comparisons may be made on the basis of frequency of streams, lakes, and swamps or any other topographic feature which is present and measurable. The soil map, since it affords the measurable acreage of different kinds of soil, also can be effectively used in making the quantitative comparisons of land types.

If the geographer wishes to take advantage of the opportunity open to him to enter the field of rural land planning and soil conservation, an opportunity which has been brought to his attention by Dr. K. C. McMurry,[4] certainly he will need to have a

[3] J. O. Veatch, "Natural Geographic Divisions of Land," *Papers of the Michigan Academy of Science, Arts, and Letters,* XIV, (1930), 417–432; and, J. O. Veatch and N. L. Partridge, *Utilization of Land Types for Fruit Production, Berrien County, Michigan,* Spec. Bul. 257, Michigan Agricultural Experiment Station, 1934.

[4] K. C. McMurry, "Geographic Contributions to Land-Use Planning," *Annals of the Association of American Geographers,* XXVI, No. 2 (June 1936).

critical understanding of the soil type and the soil map, such as is made by the Soil Survey Division of the U. S. Department of Agriculture. He might even expand his field technique and make his own soil maps for any particular local area.

It is a principle of ecology that the nature of plants and animals, or associations of them, in any region, is a function of all of the natural environmental factors. If geography is the study of man in relation to his natural environment, or human ecology, it follows that the kinds and distribution of population and the occupance or uses made of land are also, in the last analysis, a function of all of the natural environmental factors. And, as in the case of plants and animals, any attempt to work out correlations with any single factor results only in partial explanations and half-truths. Logically, therefore, systematic geographic studies shoul be tied to those divisions of land which combine the greatest number of natural factors which affect the life of man. The main excuse for this paper is to suggest that the environmental factor of soil be recognized as one of the criteria in the differentiation of natural regions. The kind of natural region which would be most useful in human ecology would be one which possessed unity in climate, physiography, topography, native vegetation, and soil. There should be a name for such a division to distinguish it from physiographic. For want of an established term the word "pedonomorphic" is suggested. Possibly the geographer could construct his own type of land divisions and thereby take a step toward making geography a more independent science than it is at present.

REVIEWS AND ABSTRACTS OF STUDIES

AGRICULTURAL GEOGRAPHY

Weaver, John C.: *American Barley Production, A Study in Agricultural Geography.* ii and 115 pp.; maps, table, Burgess Publishing Company, 426 South Sixth Street, Minneapolis, Minn., 1950. $3.00. 11×8½ inches.

Barley is one of the most significant of the grain crops, and was raised for food for thousands of years prior to its introduction into America by the earliest settlers. It commonly has taken an important place along the agricultural frontier, and its wide ecologic range has permitted its growth in many parts of America.

Dr. Weaver points out that at the beginning of the 19th century southeast Pennsylvania and Rhode Island were important barley producing areas, and supplied the strong demand for malt along the east coast. By 1820, however, the center of production had moved to the Mohawk Valley in New York, giving that state a pre-eminence which it was destined to hold for several decades. Toward the middle of the 19th century California came upon the scene as a producer of comparable importance to New York. The period of codominance of New York and California lasted until 1889, although appreciable midwest production developed before that time.

During the three decades from 1889 to 1919 there was tremenduous expansion of barley production in the United States, and important regional redistribution of the crop. The North Central States, including Michigan, Illinois, Wisconsin, Minnesota, Iowa, and the Dakotas became of prime importance. The relative significance of the eastern states declined, until by 1910, they produced only two per cent of the national barley crop. Production in recent years has continued to be sharply concentrated in the North Central States with North Dakota leading in production since 1941. Barley's competitive position is now stronger in the subhumid Dakotas than in states farther east where the farmer has a less restricted list of crops to choose from.

Considerable effort is made throughout the book to analyze the reasons for the areal distribution of production, and to explain the shift of production centers from one part of the country to another. The role of expanding transportation facilities, location of breweries, introduction of new varieties of barley, climate, soil, and many other geographic, economic, political, and social factors are considered. One section of the book is devoted to the ecological factors related to the modern distributional patterns of the crop. Here, climate and soil are considered in some detail and biologic hazards are mentioned.

One of the book's strongest points is its fine maps. Dot maps, showing the distribution of barley production for each decade from 1839 to 1939 for the whole United States, portray in excellent fashion the shift in areal production. Although it is regrettable that a change in the basis of these maps from bushels to acres had to be made, they still may be meaningfully compared. Enlarged scale maps for the North Central States depict the production patterns in those states for the period, 1939 to 1947. Other maps of the North Central States show areal increase and decrease in production in 1945 as compared to 1939, and in 1947 as compared to 1945. Per acre production, origin of cars of malting barley, and other information also has been plotted on maps. It is a pleasure to see a piece of research which has utilized the map so extensively.

Dr. Weaver has made a contribution both to economic and historical geography. Comparable studies on corn, wheat, and other crops would also be extremely valuable.

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STRATEGIC INTELLIGENCE

Kent, Sherman, *Strategic Intelligence for American World Policy.* xiii and 226 pp.; index. Princeton University Press, Princeton, 1949. 8¼×5½ inches.

The author of this book knows what he is talking about. As the publisher's jacket states, Sherman Kent was in the forefront of American intelligence activities from 1941 to 1947, first with OSS and later as acting Chief of the Office of Research and Intelligence in the Department of State where this reviewer recalls his perspicacity with respect. He is a

professor of history at Yale and wrote his book as a Guggenheim Fellow.

Mr. Kent regards intelligence as having three heuristically distinct phases: knowledge, organization, and activity. The book is divided therefore into three major parts corresponding to these phases. The first part deals with the problems of what can and should be known, how the body of knowledge gathered can be kept up to date, and to what extent predictions can be made on the basis of the evidence gathered. The second part describes the structures and functions of intelligence organizations both central and departmental and the problems arising therein. The third part deals essentially with the application of intelligence as knowledge and organization to particular problems. These three phases in reality overlap, of course, but their separation makes for an effective presentation.

The kind of intelligence organization in which Mr. Kent believes resembles closely the old Research and Analysis Branch of OSS, modified in some ways in the form of the existing Central Intelligence Agency, and further refined to provide an atmosphere of jobwise security and of intense scholarship, resembling that of a leading research university. His approach to many of the organizational and administrative problems facing the intelligence organization is a common sense one. He recognizes the importance of personal contact in smoothing inter-agency relations and the value of having administrative control at least partly in the hands of men taken from the working staff or at least with its problems clearly in mind. The conflicts which are bound to arise from the competition between central and departmental agencies are discussed at length. The unfortunate hiatus between language translator and analyst and between regional specialist and systematic specialist also are examined, not too successfully perhaps, but with understanding.

The first part of the book is of the greatest interest to geographers. Mr. Kent's concept of intelligence as knowledge includes a so-called "descriptive element" which is maintained currently by a "reportorial element" and which is in turn the basis for a "speculative-evaluative element," the immediate end for procurement and analysis of intelligence data. The first and basic element consists of a series of national and regional studies similar in form to the JANIS studies published during the war and familiar to many geographers.

In theory all phenomena would be included within these regional descriptions; in reality such descriptions are impossible. The problem that arises is essentially the same as that which faces the regional geographer: once the criteria of homogeneity are selected for a region (in this case perhaps the national political unit) what other elements are significant to the understanding of the regional complex? The geographer turns to some particular question or problem in area; the intelligence officer must do likewise, if with lesser specificity. The approach of intelligence in this sphere, however, is to provide background for detailed or "narrow-deep" studies. The regional geographer's immediate objective is regional characterization as a means for understanding areal differentiation.

Mr. Kent's conclusion that the organization of a central intelligence agency should be primarily regional is in keeping with his apparently strong geographical bent concerning the importance of terrain and areal analysis and the appraisal and evaluation of resources within a national and cultural frame. Still, in recommending this type of organization he is troubled by the difficulties involved in properly covering certain systematic topics of world wide concern. However, the problem may not be as acute as it first appears. The kind of knowledge with which intelligence is concerned is *specific* not *general* knowledge. That is, intelligence is expected to apply the general laws and principles of science to particular situations; it is not expected to develop such principles on its own. In the case of the Catholic Church, for example, it could hardly be the function of an intelligence research agency to determine the cultural and political influences which the Church has had and still has on world civilization. Such general conclusions may be supplied by specialized historians and other social scientists. In the intelligence organization, however, the Church as a factor in the social structure of *specific* areas or nations would be treated within the regional division responsible for those areas, and the general nature and functions of the Church could be derived from without.

Along the same line, as Mr. Kent points out the most desirable situation is for the systematic specialist and the regional specialist to be combined in one person. If this is not wholly possible, at least with time the systematic specialist, working on problems within his competence in one area, will tend to approach this synthesis, at the same time maintaining his relations with his own field for general principles which might be applied to his particular area. The problems with which

the intelligence specialist deal are localized and specific, in other words "realistic"; the problems of the academic specialist, other than the geographer, are more often general and nonlocalized and therefore less "realistic."

Despite the apparent value of the book this reviewer was left with a feeling of no little unease. Perhaps this was due in part to the extreme informality of the language and the author's desire to elucidate clearly, as shown in the following quote from a footnote on page 69: "It goes without saying that the first quality of a *clandestine* observer is an impenetrable cover or disguise, which at the same time does not unduly restrict his observational activities. He should have other things besides cover, many of which are the same as those to be described for the overt observer."

More probably it derives from the uncertainty concerning the nature and purpose of 'intelligence as knowledge.' As the title of Mr. Lynd's book on the back cover of the wrapper asks: "Knowledge for What?" In his Preface Mr. Kent speaks of knowledge "vital for national survival." Yet there are major subject fields in science and philosophy which may be of greater long run importance for national survival than the kinds of knowledge included under 'intelligence as knowledge.' The issue must be faced squarely. Intelligence derives its *raison d'etre* from conflict, whether in times of peace or of war. Its goal at all times is not the maintance of peace nor the provocation of war, but preparedness for the latter. Incidental goods useful for other ends may develop in the process, but these are almost always peripheral and subsidiary to the primary objective.

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